Front End Progress

John Staples, Qing Ji

March 2011

Issues

New RFQ beam dynamics design

RFQ output energy

RFQ cavity for new beam dynamics design

MEBT modeling with Astra

Chopping in LEBT: emittance growth

LEBT R&D program

RFQ Cavity engineering

MEBT engineering

Limited-bandwidth MEBT chopper

Beam absorber engineering

New RFQ design.

Lower injection energy

Higher capture

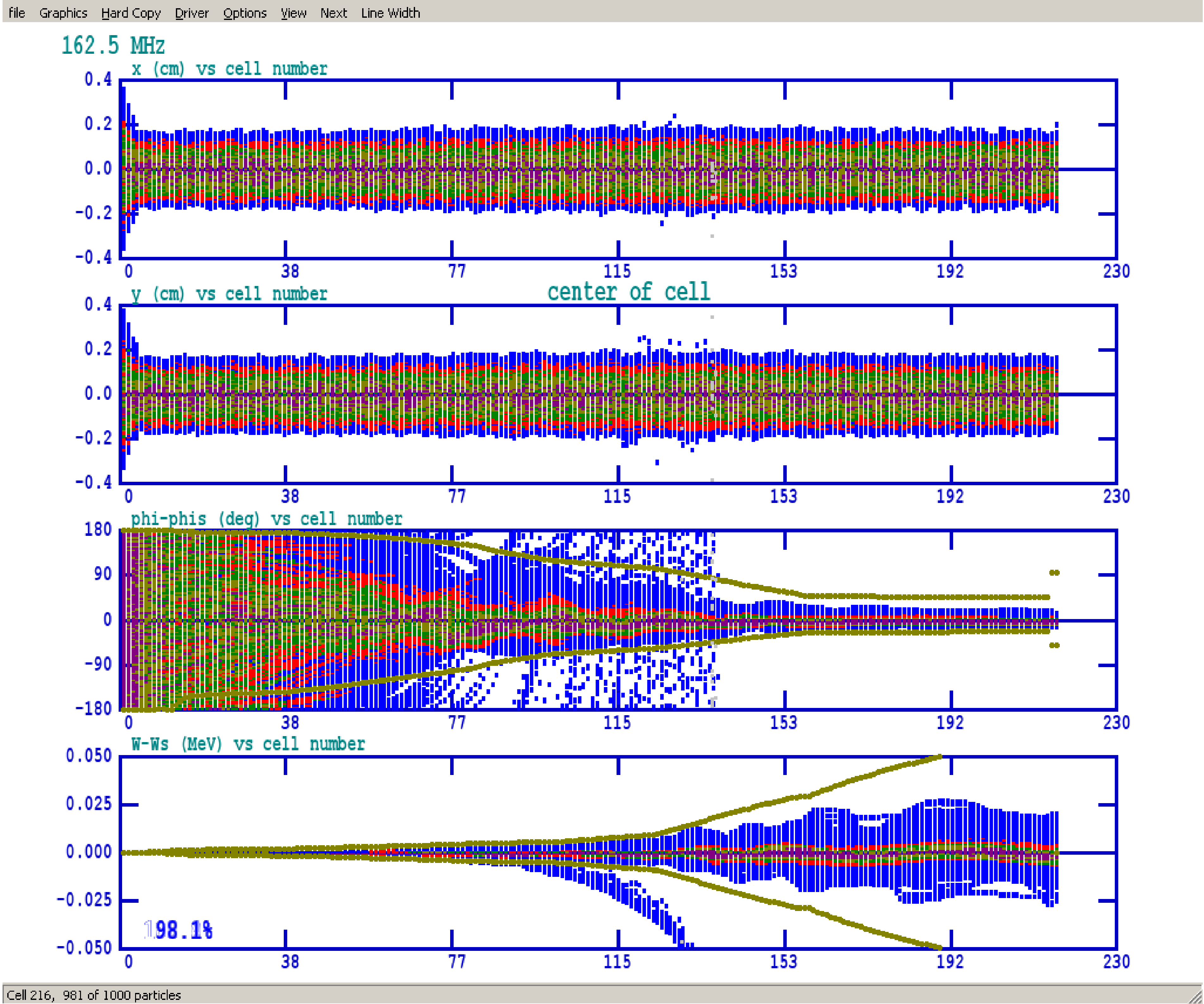
Lower power requirement

Lower surface field

Lower output emittance

2.1 and 2.5 MeV options

	V1	V2a	V2b		
Duty Factor	100	100		percent	
Input Energy	35	20		keV	
Output Energy	2.5	2.1	2.5	MeV	
Length	384	404	489	cm	length of vanes
V_{vv}	90.8	68		kV	intervane voltage
N_{cells}	135	212	228		
Input current	5	5		mA	
Transmission	93.7	97.8		percent	
Transverse Loss		0.05		percent	transverse beam loss on vanes
Longitudinal Loss		2.2		percent	beam out of bucket
B	9.0	9.0			focusing parameter
P'/cm	402	180.3		watts/cm	copper power per linear RFQ length
P_{copper}	154	73	88	kW	Superfish power, 100% Q_0, no ends
P_{beam}	12.5	10.5	12.5	kW	beam power
P_d	2.05	0.90		W/cm^2	max wall power density
L/λ	2.1	2.2	2.6		length/free-space wavelength
E_{max}	20.8	16.4		MV/m	peak vanetip field
kilp	1.53	1.21		kilpatrick	peak vanetip field
r_0	0.605	0.521		cm	average vane tip dist from axis
$r_{long, min}$	1.18	1.87		cm	minimum long radius of curvature
r_{transv}	0.605	0.391		cm	vane tip transverse radius
a_{min}	0.395	0.316		cm	minimum aperture
cavity radius		17.5		cm	max outer cavity wall dimension
$\epsilon_{x,y\ in}$	0.0250	0.0250		cm-mrad	normalized transverse input emittance
$\epsilon_{x,y}$	0.029	0.0254		cm-mrad	normalized transv output emittance
ϵ_z	0.0279	0.0158	0.0172	cm-mrad	normalized longitudinal emittance
ϵ_z	51.1	28.9	31.5	keV-deg	longitudinal output emittance
ϵ_z	0.88	0.49	0.54	keV-nsec	longitudinal output emittance



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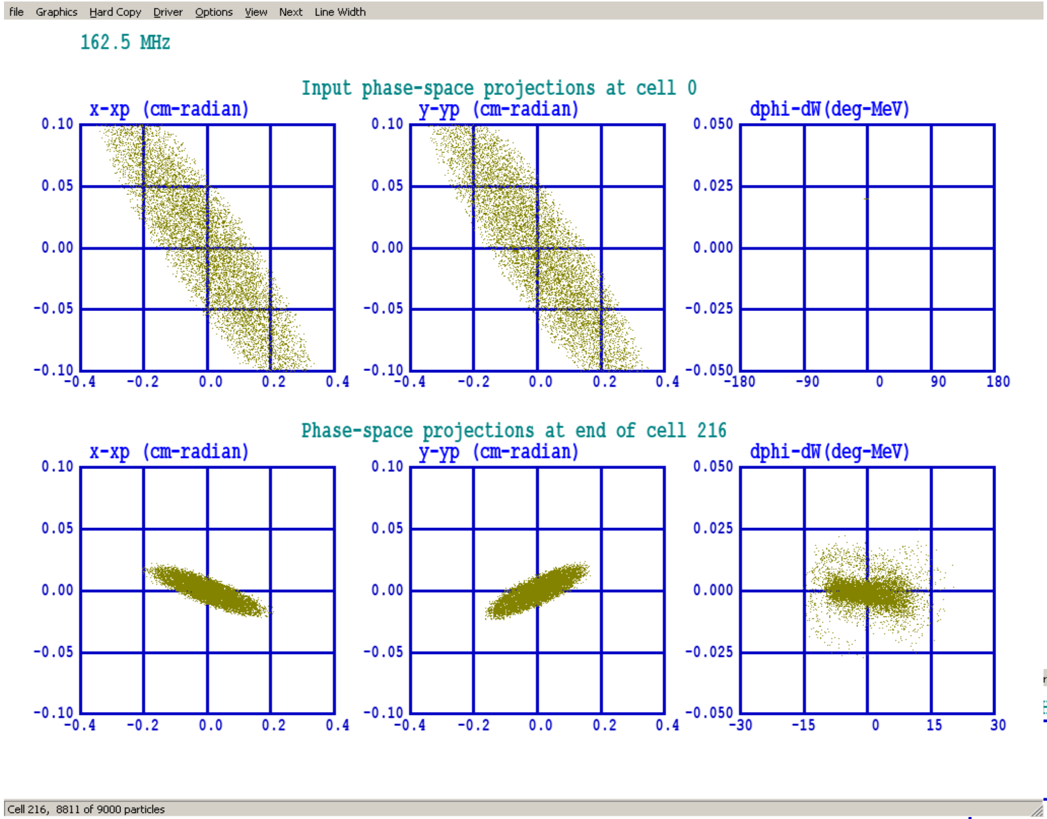
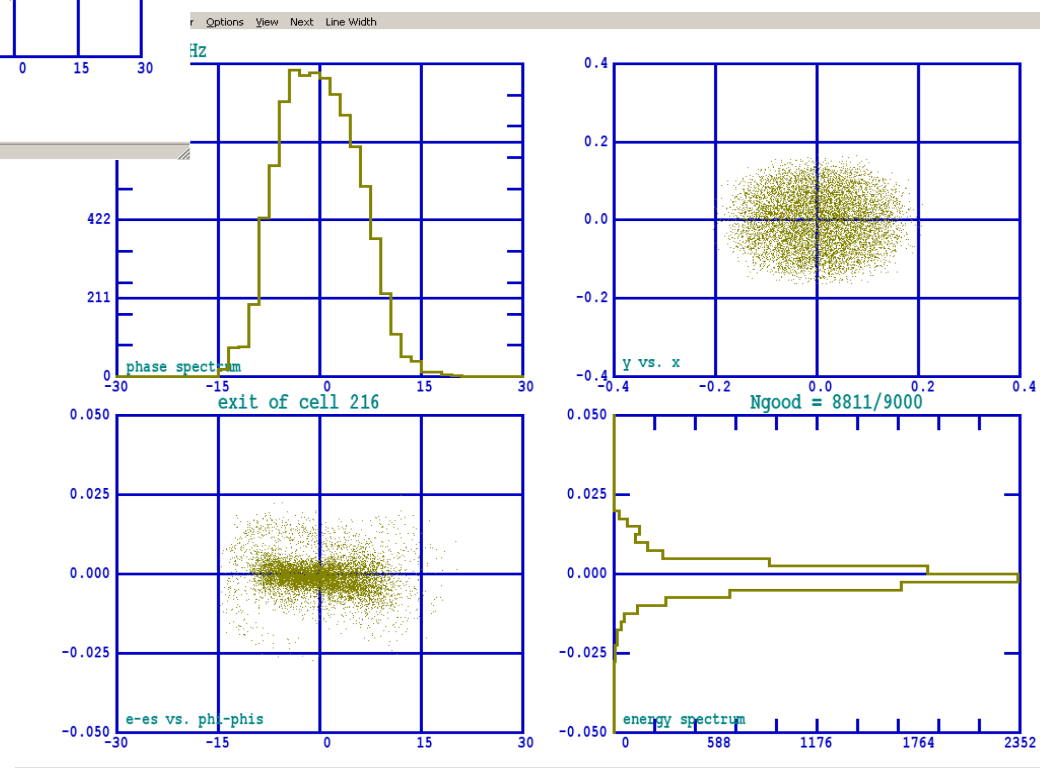
162.5 MHz
x (cm) vs cell number
0.4
0.2
0.0
-0.2
-0.4
0 38 77 115 153 192 230
y (cm) vs cell number
center of cell
0.4
0.2
0.0
-0.2
-0.4
0 38 77 115 153 192 230
phi-phis (deg) vs cell number
180
90
0
-90
-180
0 38 77 115 153 192 230
W-Ws (MeV) vs cell number
0.050
0.025
0.000
-0.025
-0.050
98.1%
0 38 77 115 153 192 230
Cell 216, 981 of 1000 particles



Longitudinal output phase space and distributions.

Longitudinal emittance 0.50 keV-nsec



Transverse phase space at entrance and exit (same scales).

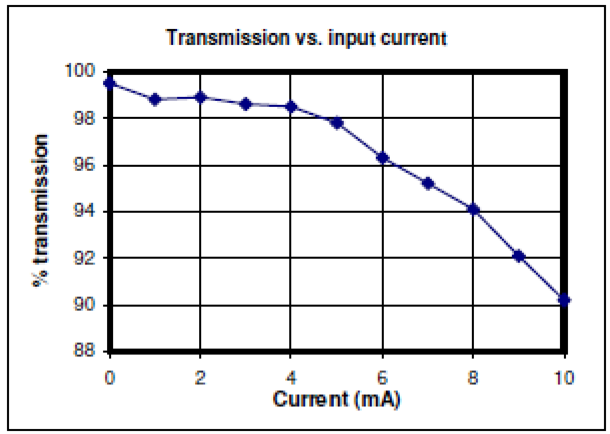
Waterbag input beam distribution, 0.25 pi mm-mrad rms emittance

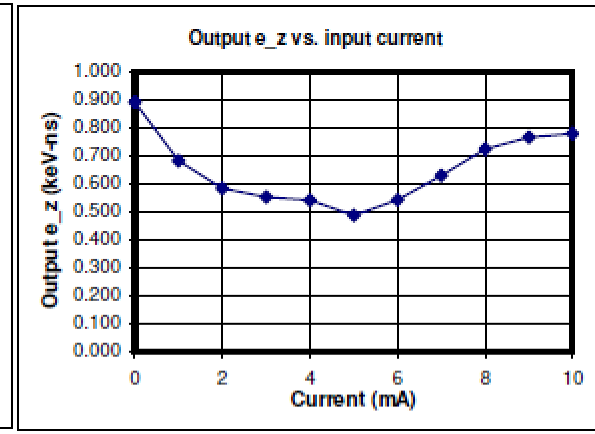
RFQ beam parameter dependence (Qing Ji)

Transmission and output emittance vs. current and input emittance.

Response of RFQ 23Feb11

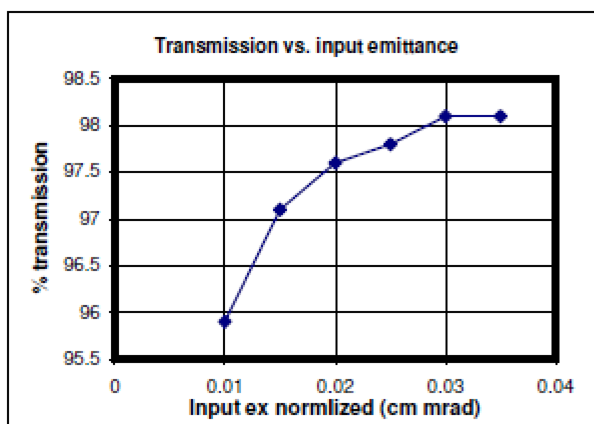
I (mA)	Transm. (%)	e_z (cm-mrad)	e_z (keV-ns)
0	99.5	0.02857	0.890
1	98.8	0.02185	0.681
2	98.9	0.01869	0.582
3	98.6	0.01769	0.551
4	98.5	0.01733	0.540
5	97.8	0.01559	0.486
6	96.3	0.01736	0.541
7	95.2	0.02016	0.628
8	94.1	0.02318	0.722
9	92.1	0.02454	0.765
10	90.2	0.02496	0.778

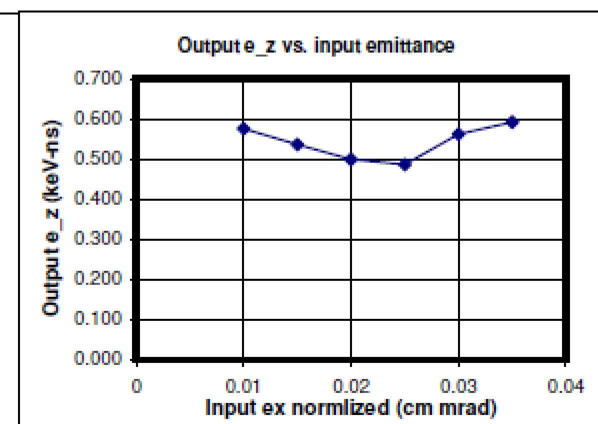




Response to input emittance, current - 5mA

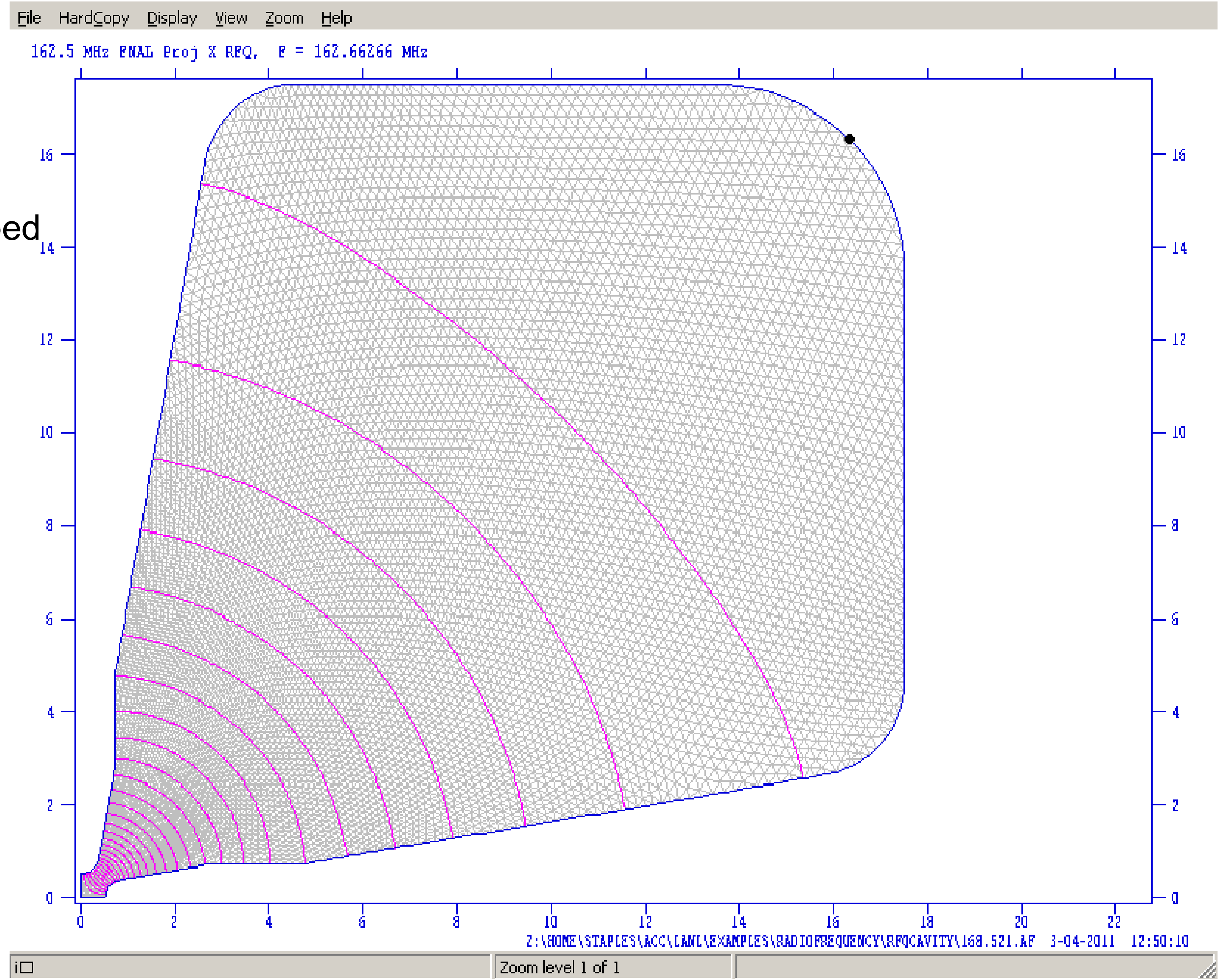
n (cm m	Transm. (%)	e_z (cm-mrad)	e_z (keV-ns)
0.01	95.9	0.01846	0.575
0.015	97.1	0.01719	0.536
0.02	97.6	0.01601	0.499
0.025	97.8	0.01559	0.486
0.03	98.1	0.01802	0.562
0.035	98.1	0.01899	0.592





RFQ cavity reshaped for new geometry near vane tips.

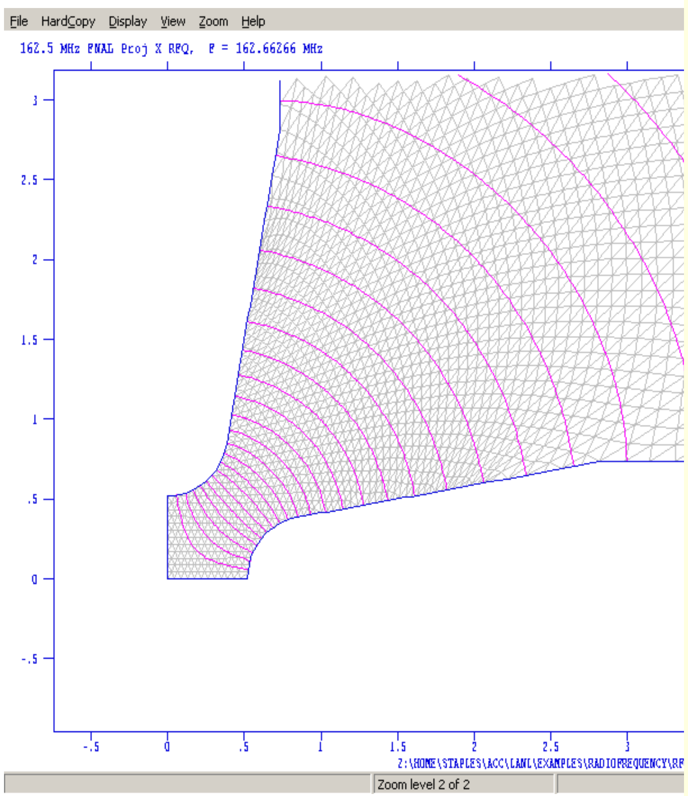
$r_{transv} = 0.75\ r_0$



Lower power level

Lower peak fields

Lower wall power density less that 1 W/cm[2]

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Superfish output summary for problem description:
162.5 MHz FNAL Proj X RFQ,
Problem file: Z:\HOME\STAPLES\ACC\LANL\EXAMPLES\RADIOFREQUENCY\RFQCAVITY\168.521.AF   3-04-2011
-------------------------------------------------------------------------------
All calculated values below refer to the mesh geometry only.
Field normalization (NORM = 0):     EZERO =      6.52591 MV/m
Frequency                                 =    162.66266 MHz
Normalization factor for E0 =  6.526 MV/m =     8679.912
Stored energy                             =  7.28645E-04 Joules/cm
Using standard room-temperature copper.
Surface resistance                        =      3.32740 milliOhm
Normal-conductor resistivity              =      1.72410 microOhm-cm
Operating temperature                     =      20.0000 C
Power dissipation                         =      44.6260 W/cm
Q    =   16687.7           Shunt impedance =     4972.012 MOhm/m
r/Q  =    36.449 Ohm   Wake loss parameter =      0.00931 V/pC
Average magnetic field on the outer wall  =      2270.39 A/m, 857.583 mW/cm^2
Maximum H (at X,Y = 16.3284,16.3284)      =      2304.06 A/m, 883.205 mW/cm^2
Maximum E (at X,Y = 0.625753,0.265591)    =      16.3531 MV/m, 1.20243 Kilp.
Ratio of peak fields Bmax/Emax            =       0.1771 mT/(MV/m)
Peak-to-average ratio Emax/E0             =       2.5059
```

Wall segments:

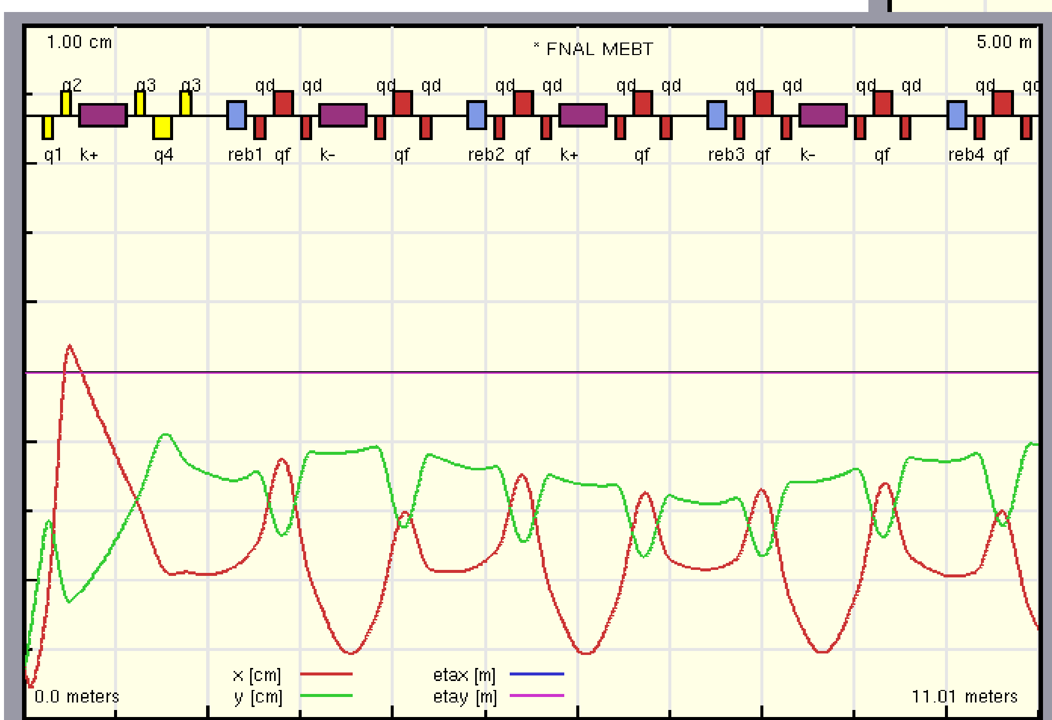
Segment	Xend (cm)	Yend (cm)	Emax (MV/m)	Power (W)	P/A (mW/cm^2)	dF/dX (MHz/mm)	dF/dY (MHz/mm)
	0.0000	0.52100					
2	0.25130	0.61250	16.25	1.9979E-03	7.323	1.086	2.805
3	0.38510	0.84410	16.34	1.4960E-02	54.83	2.481	1.557
4	0.60655	2.1000	11.33	0.2652	207.9	1.973	0.3478
5	0.73240	2.8137	3.065	0.2502	345.3	0.2416	4.2605E-02
6	0.73240	4.8137	2.365	0.9360	468.0	0.1857	0.000
7	1.1120	7.0000	0.9187	1.298	584.8	1.9746E-02	3.4287E-03
8	2.1000	12.690	0.6917	4.191	725.7	-0.1143	-1.9840E-02
9	2.6483	15.847	0.2535	2.613	815.2	-0.1037	-1.7999E-02
10	3.3324	17.032	8.4013E-02	1.163	833.4	-4.1406E-02	-2.3946E-02
11	4.6179	17.500	4.5577E-02	1.169	837.8	-1.6474E-02	-4.5298E-02
12	7.0000	17.500	7.2921E-02	2.011	844.3	0.000	-8.4333E-02
13	13.500	17.500	7.7929E-02	5.629	865.9	0.000	-0.2358
14	16.328	16.328	3.8634E-02	2.771	882.1	-4.3581E-02	-0.1051
15	17.500	13.500	3.7971E-02	2.771	882.1	-0.1051	-4.3580E-02
16	17.500	7.0000	7.7507E-02	5.629	866.0	-0.2358	0.000
17	17.500	4.6179	7.2478E-02	2.011	844.4	-8.4332E-02	0.000
18	17.032	3.3324	4.5403E-02	1.169	837.8	-4.5297E-02	-1.6473E-02
19	15.847	2.6483	8.4083E-02	1.163	833.4	-2.3947E-02	-4.1405E-02
20	12.690	2.1000	0.2519	2.613	815.2	-1.7999E-02	-0.1037
21	7.0000	1.1120	0.6918	4.191	725.7	-1.9840E-02	-0.1143
22	4.8137	0.73240	0.9221	1.298	584.8	3.4315E-03	1.9762E-02
23	2.8137	0.73240	2.356	0.9359	468.0	0.000	0.1853
24	2.1000	0.60655	3.070	0.2502	345.2	4.2720E-02	0.2423
25	0.84410	0.38510	11.24	0.2652	207.9	0.3483	1.975
26	0.61250	0.25130	16.35	1.4975E-02	54.88	1.557	2.477
27	0.52100	0.0000	16.24	2.0046E-03	7.348	2.806	1.088
			Total	44.63			

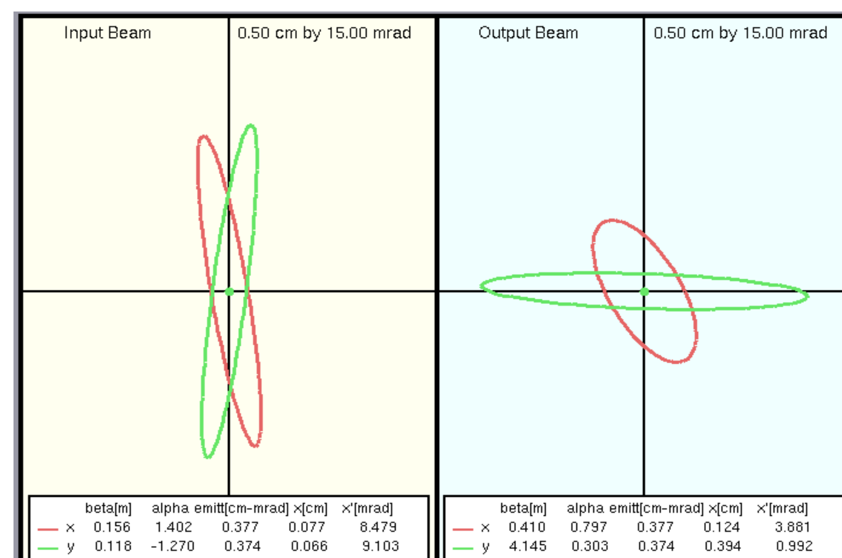
RFQ-MEBT Matching Section

Add doublet and decouple the first triplet.

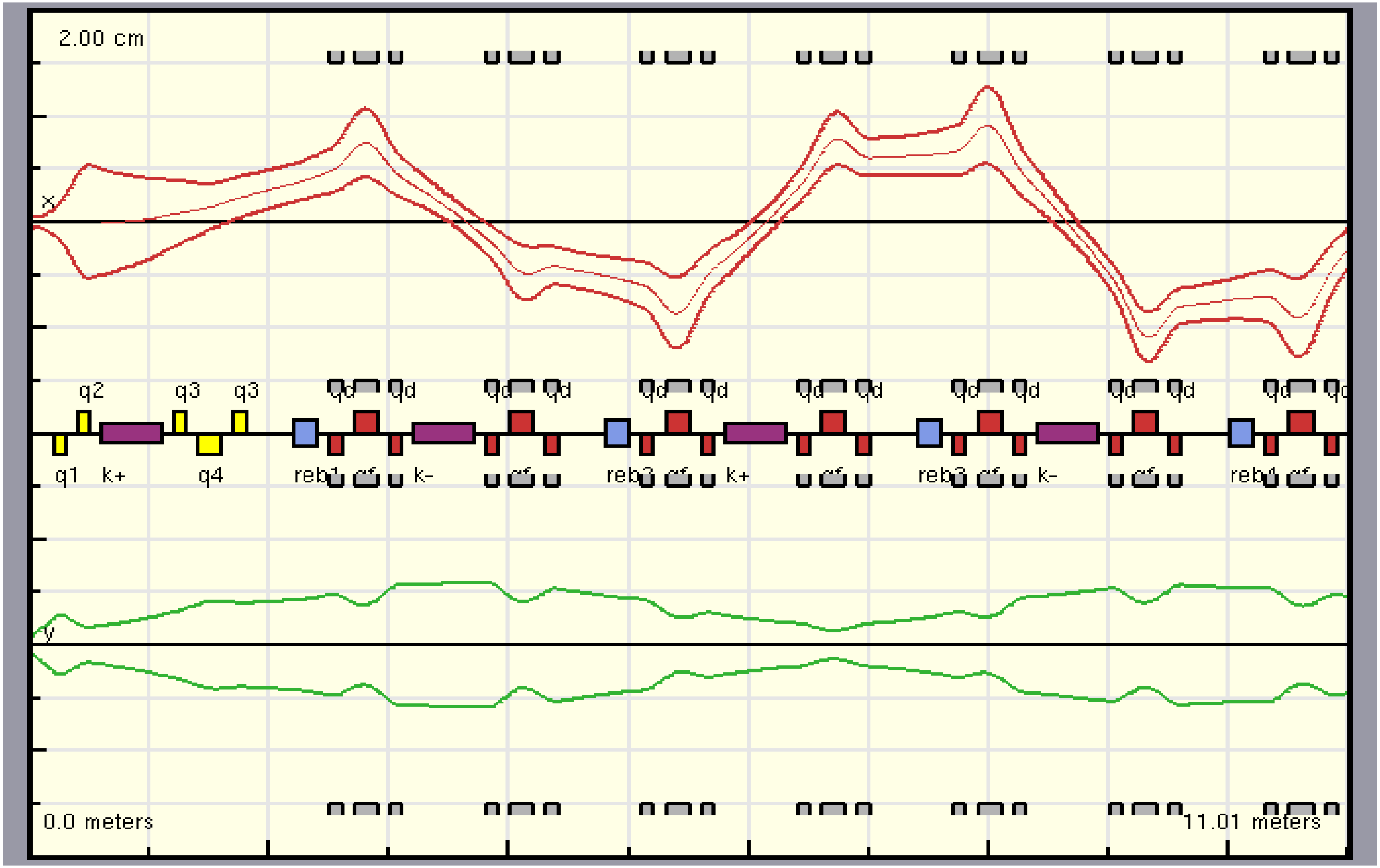
Think about adding one more rebuncher after the RFQ.

30 pcoul bunch charge (5 mA)





Beam profile in MEBT with matcher, kickers



Emittance Growth in MEBT

Macroparticle calculations with Astra with space charge

Input beam derived from output of parmteqm.
Format converter written
Parmteqm has a bug in the quadrupole transport element

Emittance growth through MEBT is dependent on details of tune

Diagnostics required for transverse beam size and centering
BPMs and laser wires

Diagnostics required for setting rebuncher gradients and phases
BPMs and/or striplines

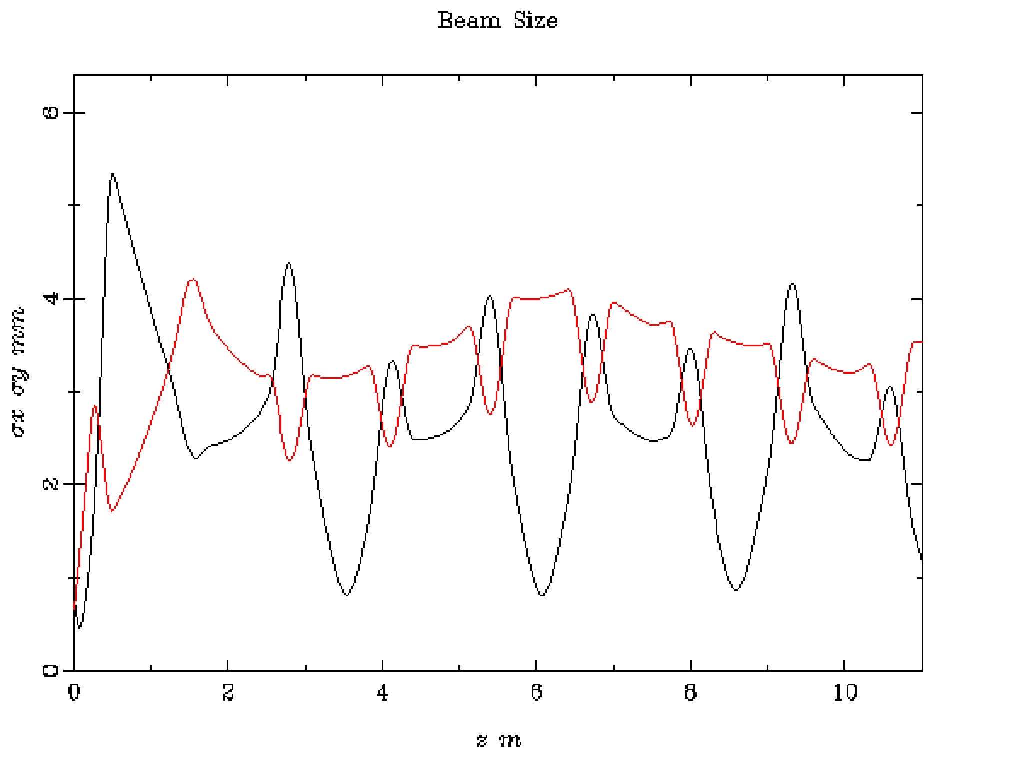
These diagnostics should not take much room

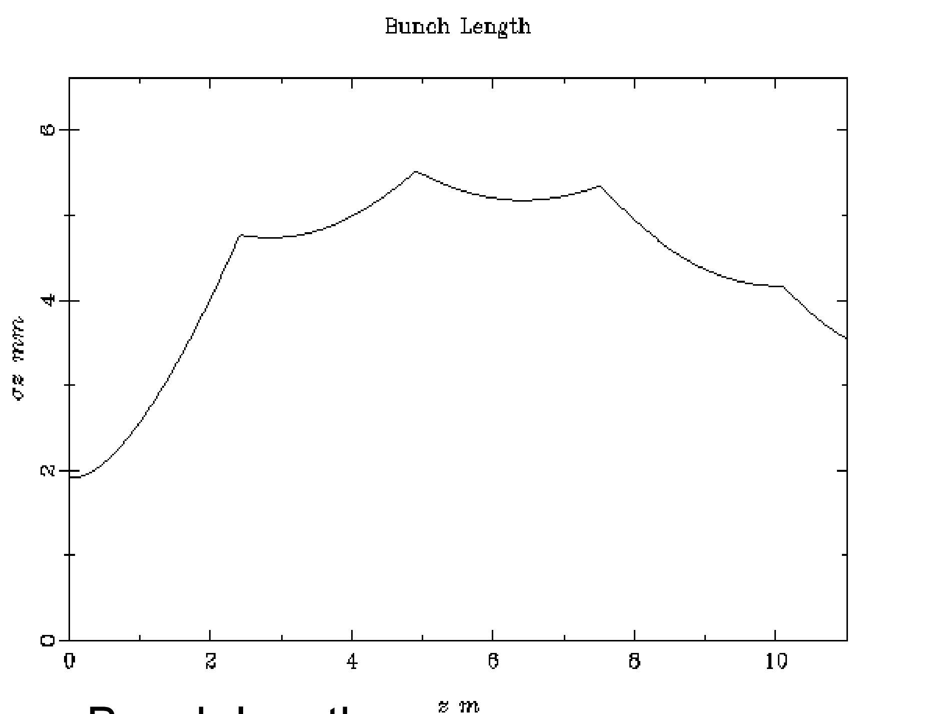
Initial RFQ emittance measurements need to be done once.

Astra run of RMS beam envelope

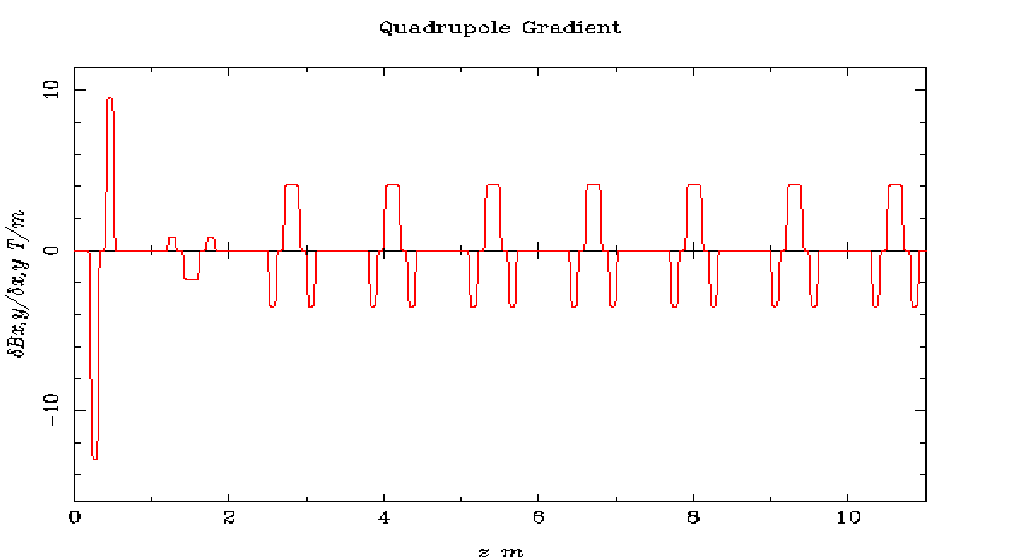
Parameters: (worst case)

- parmteqm output beam
- 30 pCoul bunch charge (5 mA)
- 2.1 MeV
- 325 MHz rebunchers 23, 10 keV
- tuned for minimum emittance growth





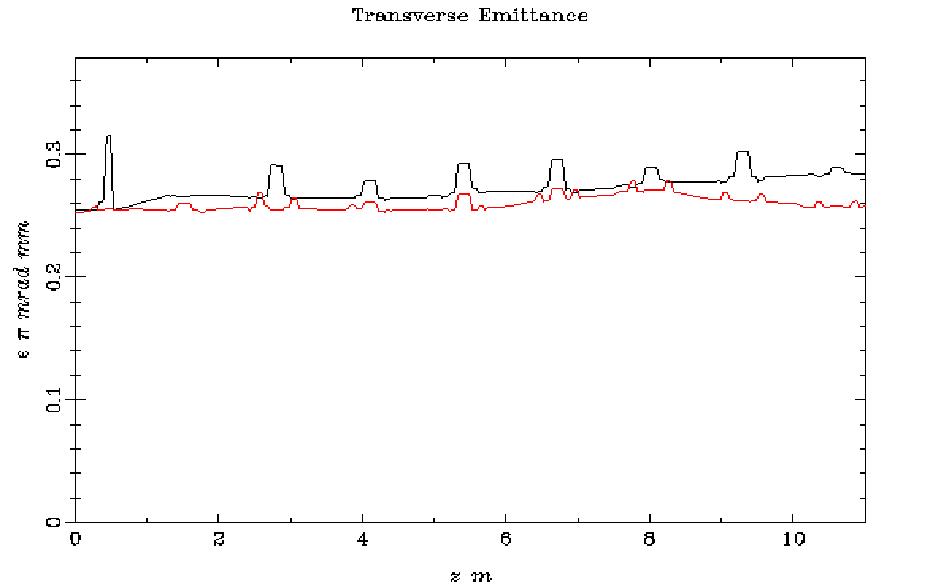
Bunch length

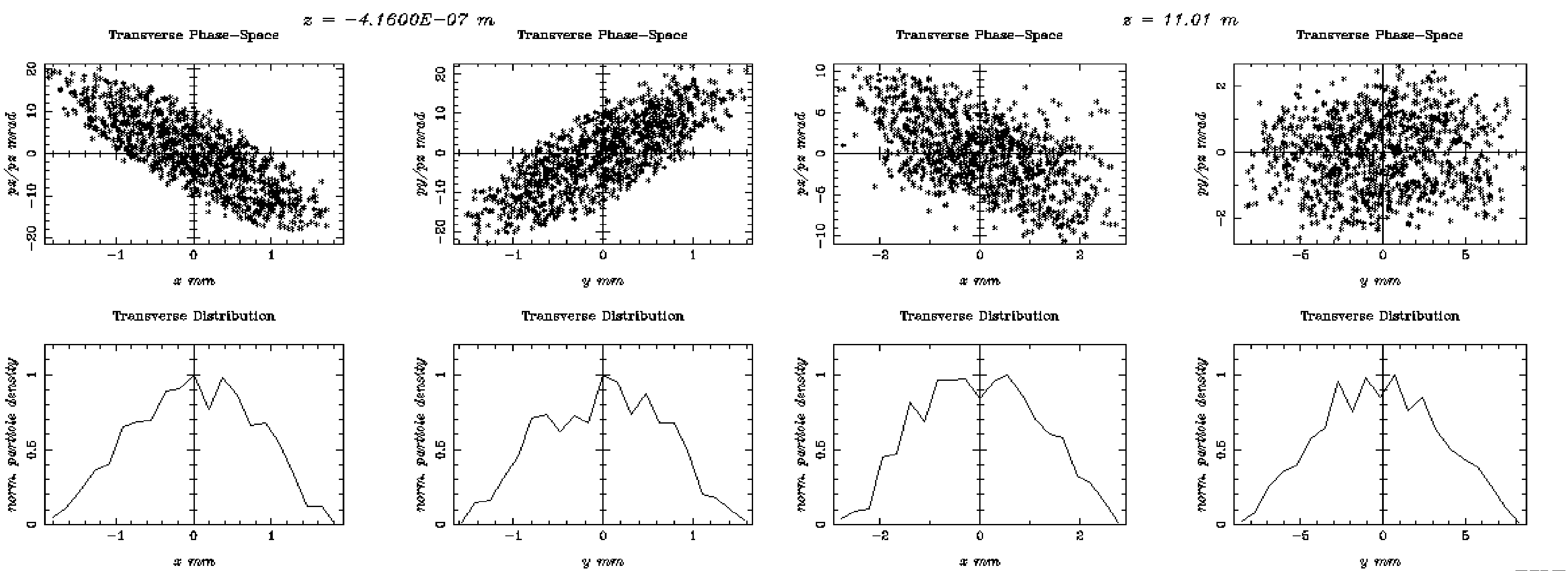


Quad gradients

Transverse emittance growth

Quads tuned to minimize growth

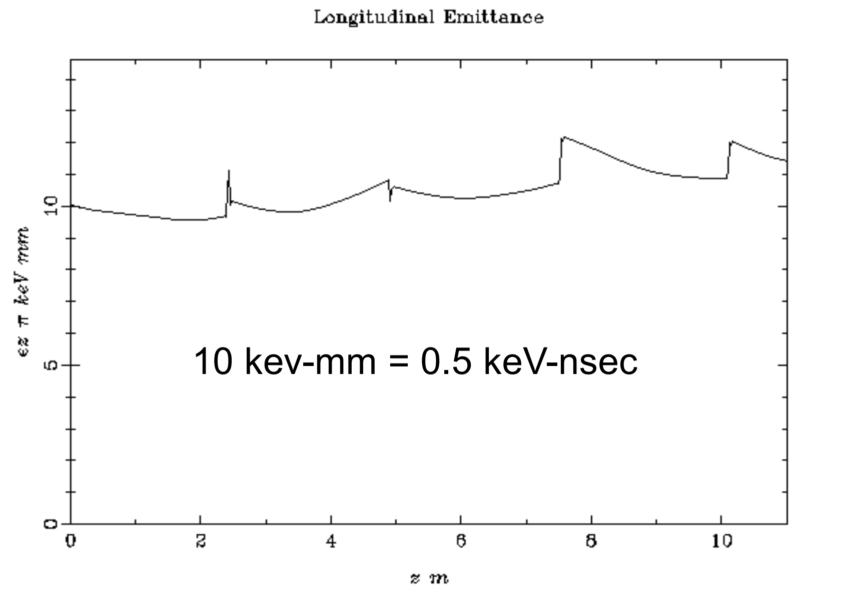


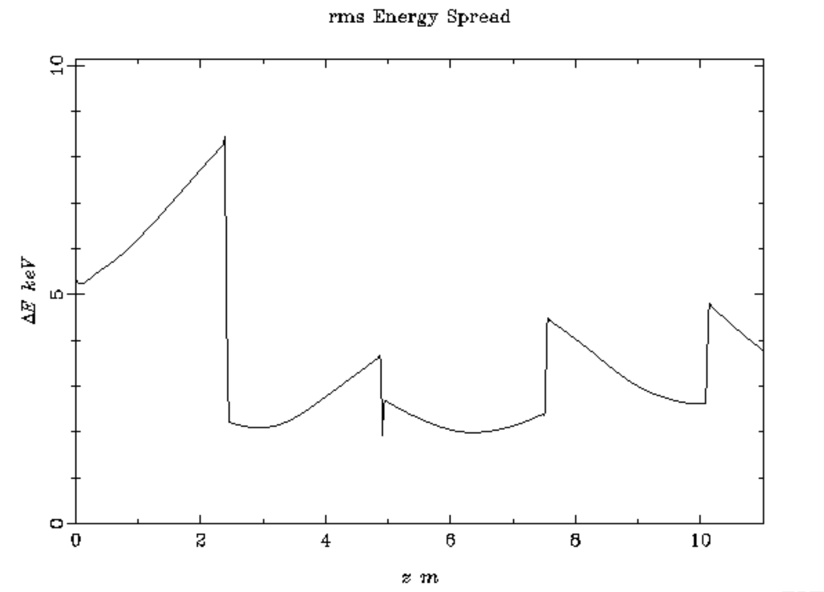


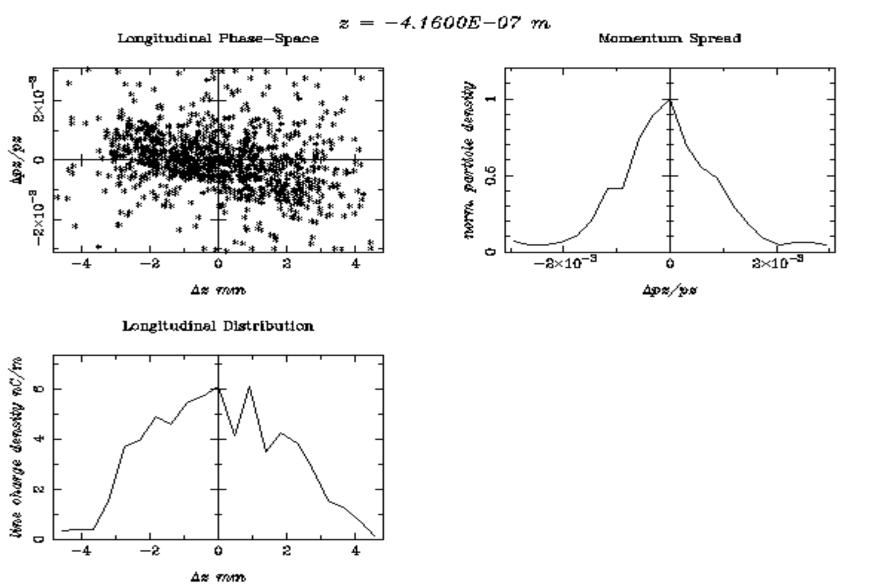
Input x,y phase space

Output x, y phase space

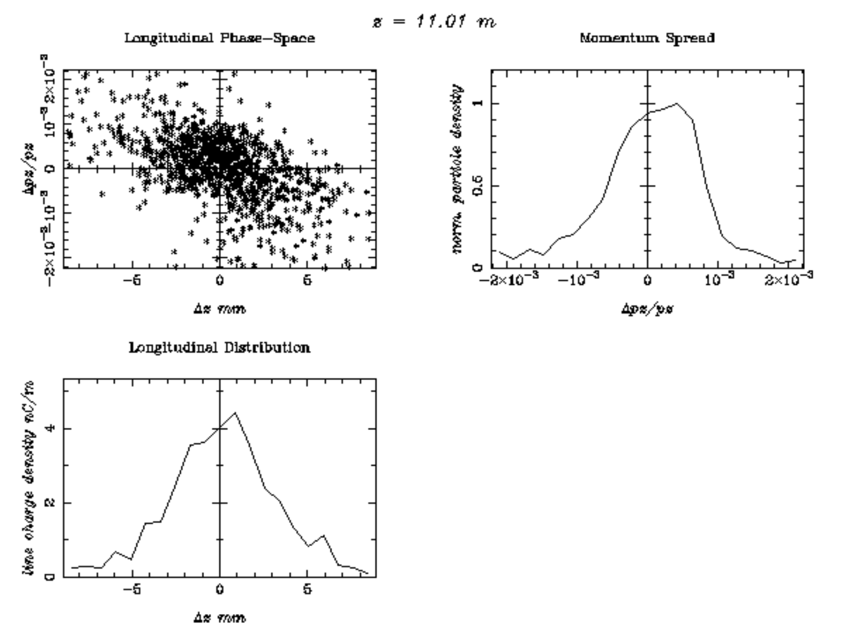
Longitudinal emittance growth





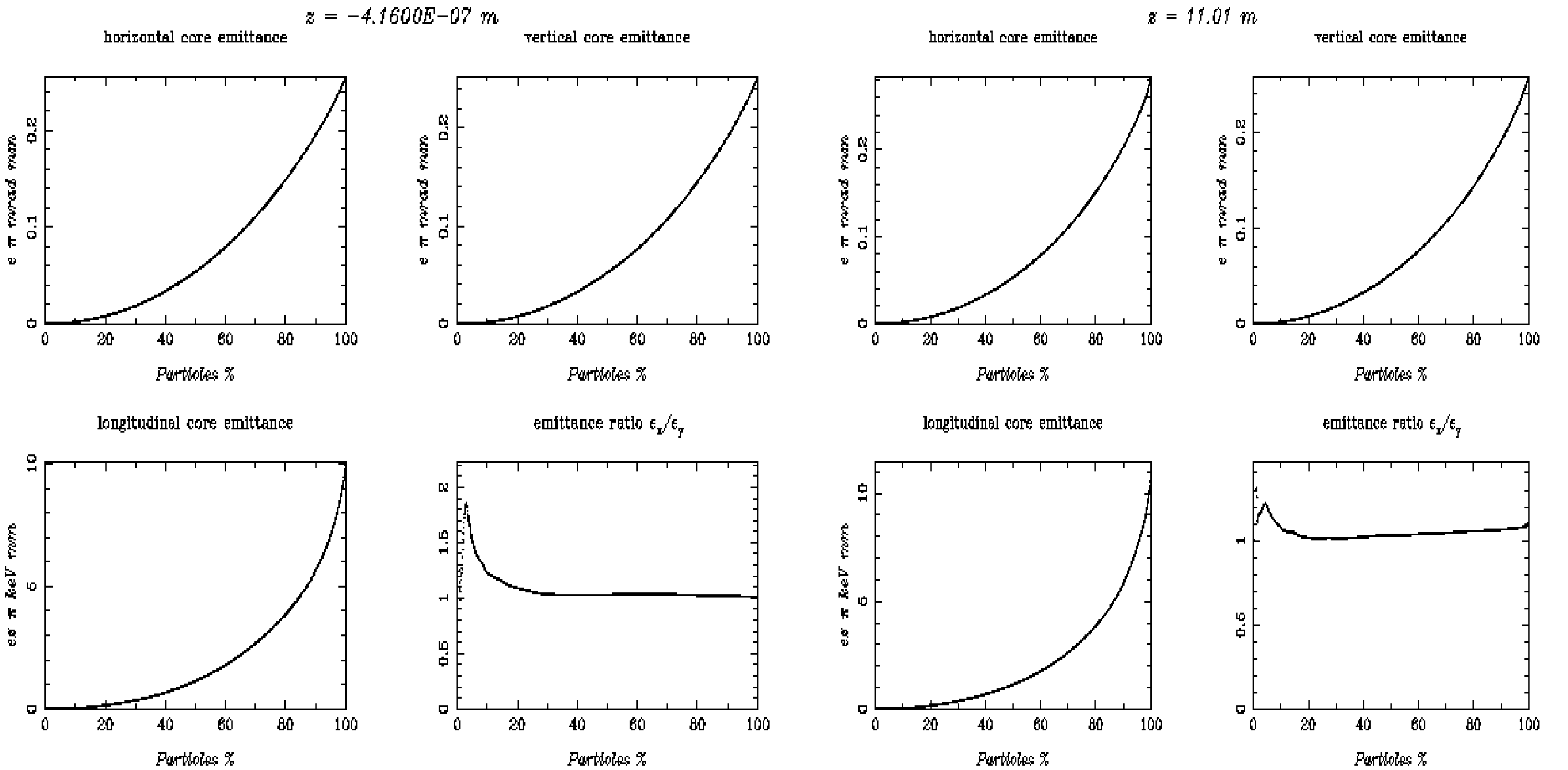


Input longitudinal phase space



Output longitudinal phase space

fractional emittance contours

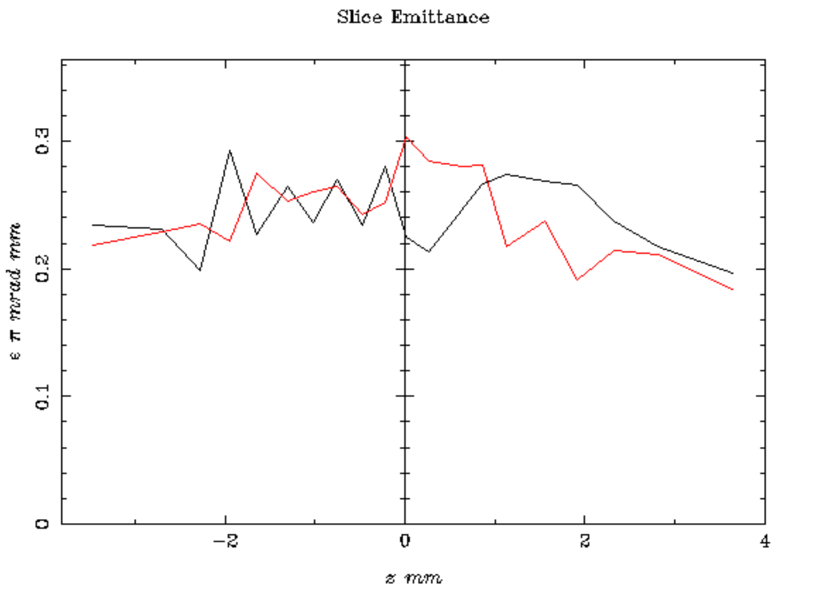


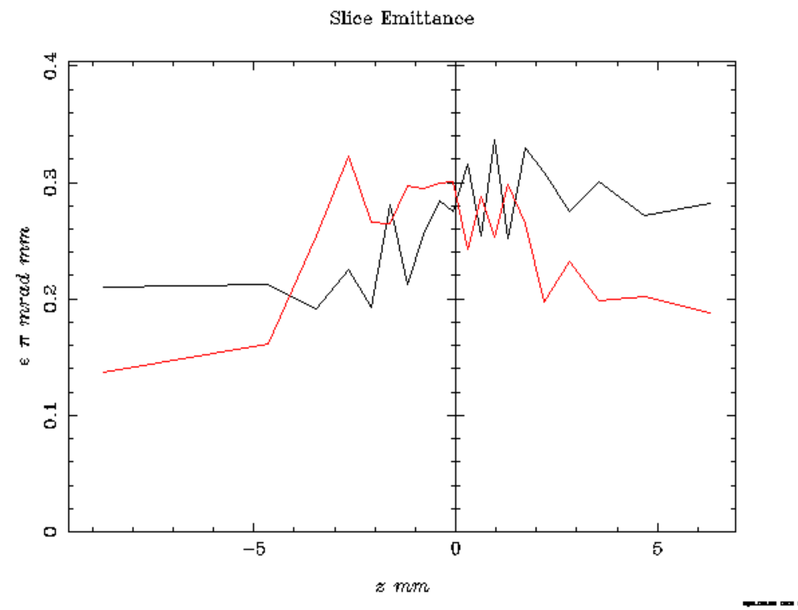
Input beam

Output beam

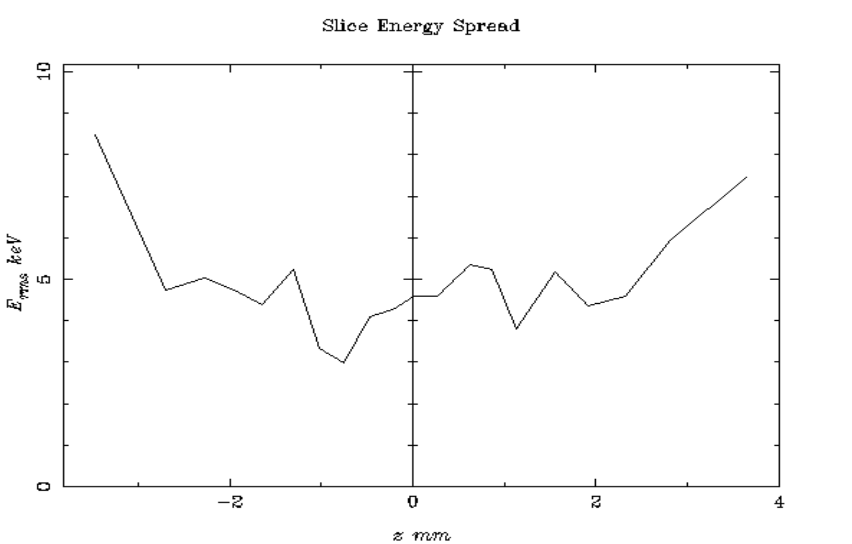
Slice emittance, energy spread

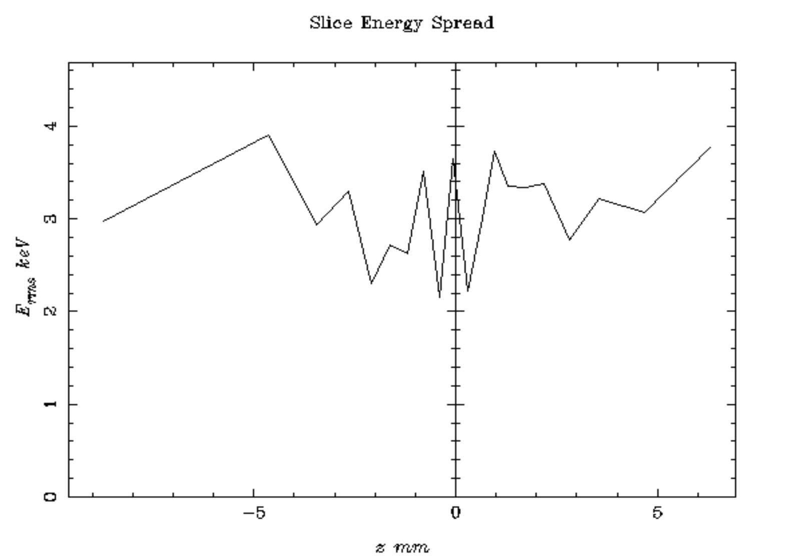
Emittance





Energy spread





MEBT entrance

MEBT exit

325 MHz Rebuncher Cavity Example

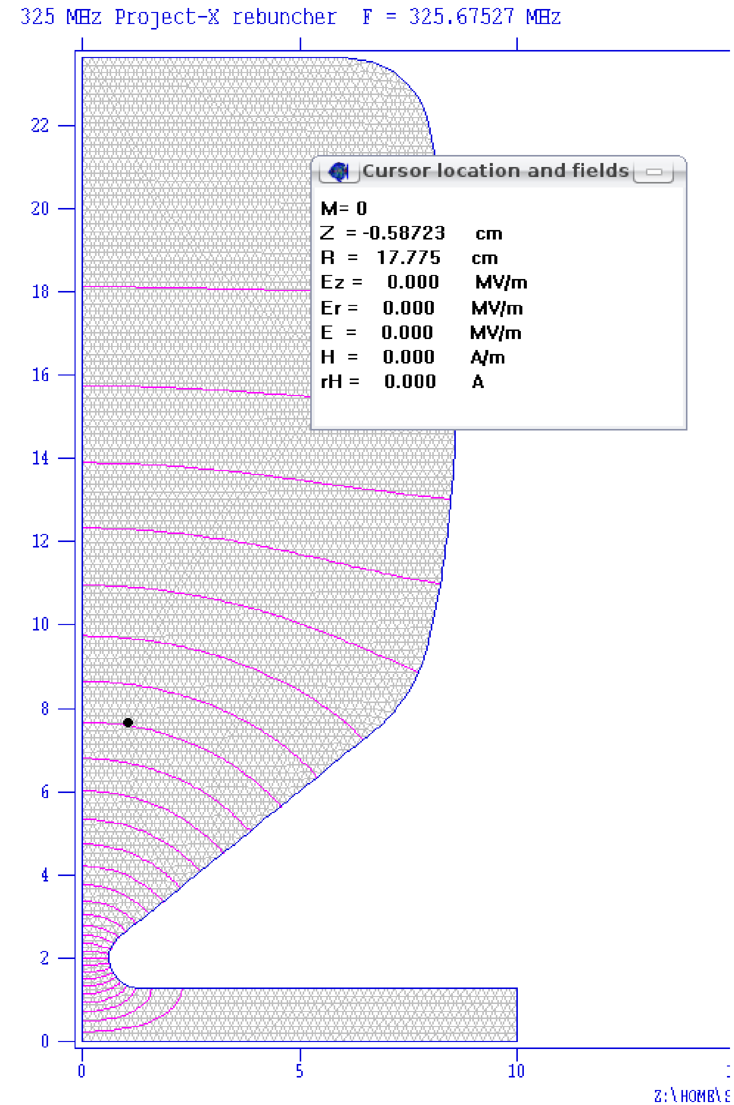
2 x E_0 x TTF = 25 kV

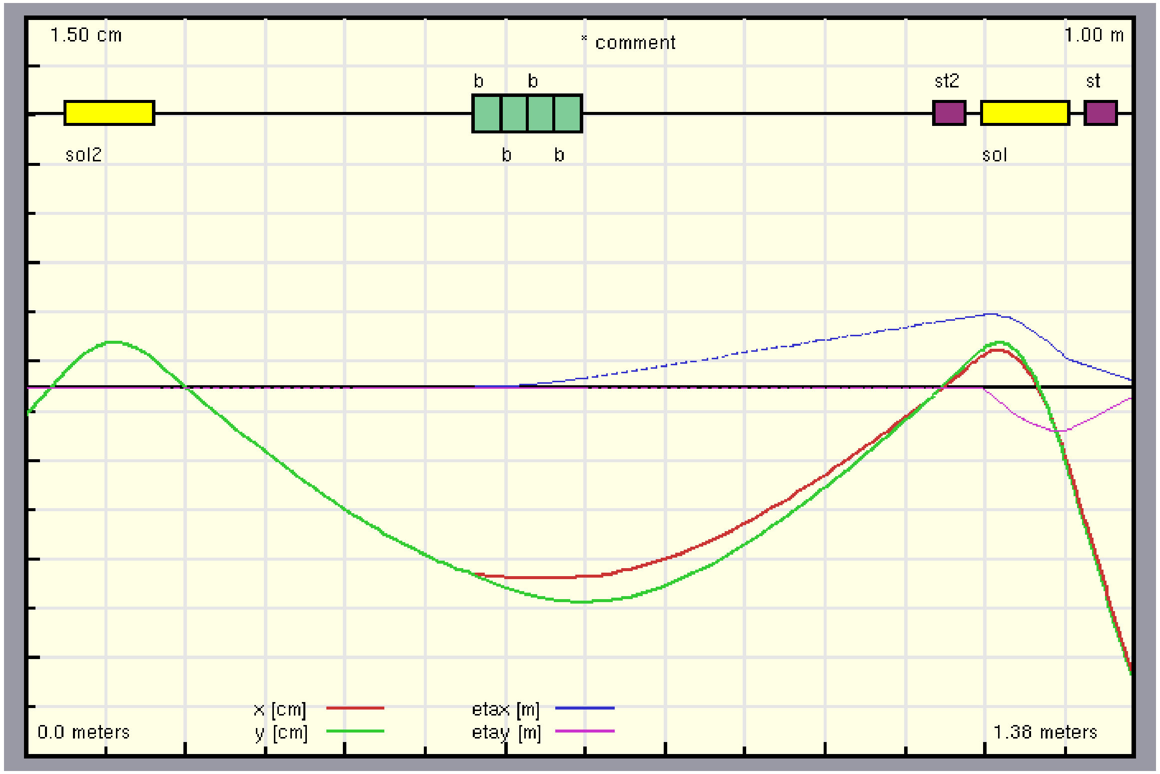
Power = 600 watts, first rebuncher

```
All calculated values below refer to the mesh geometry only.
Field normalization (NORM = 0):     EZERO =      0.21940 MV/m
Frequency                                 =    325.67527 MHz
Particle rest mass energy                 =   938.272029 MeV
Beta =  0.0671960            Kinetic energy =        2.125 MeV
Normalization factor for E0 =  0.219 MV/m =     2511.271
Transit-time factor                       =    0.5698715
Stored energy                             =    0.0023621 Joules
Using standard room-temperature copper.
Surface resistance                        =      4.70818 milliOhm
Normal-conductor resistivity              =      1.72410 microOhm-cm
Operating temperature                     =      20.0000 C
Power dissipation                         =     300.3079 W
Q   =   16095.3            Shunt impedance =       16.029 MOhm/m
Rs*Q =    75.780 Ohm              Z*T*T =        5.205 MOhm/m
r/Q  =    32.342 Ohm  Wake loss parameter =      0.01654 V/pC
Average magnetic field on the outer wall  =      389.376 A/m, 35.6913 mW/cm^2
Maximum H (at Z,R = 2.57628,3.96744)      =      941.657 A/m, 208.742 mW/cm^2
Maximum E (at Z,R = 0.6,1.97)             =      4.22106 MV/m, 0.236325 Kilp.
Ratio of peak fields Bmax/Emax            =       0.2803 mT/(MV/m)
Peak-to-average ratio Emax/E0             =      19.2391
```

Wall segments:

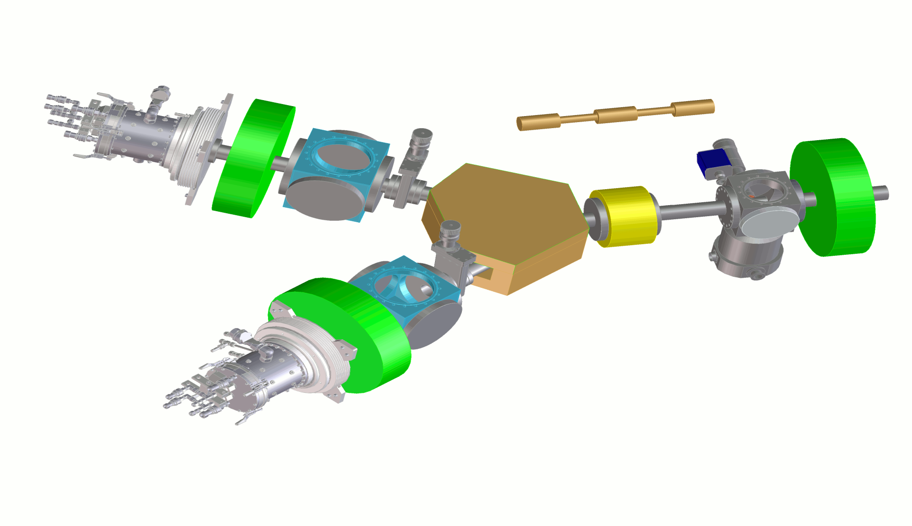
Segment	Zend (cm)	Rend (cm)	Emax (MV/m)	Power (W)	P/A (mW/cm^2)	dF/dZ (MHz/mm)	dF/dR (MHz/mm)
	0.0000	0.0000					
2	0.0000	23.630	3.139	112.3	64.02	7.142	0.000
3	6.0100	23.630	2.5938E-03	31.85	35.70	0.000	-0.5861
4	7.9700	22.030	1.4319E-02	14.73	37.13	-0.1591	-0.1926
5	8.6000	15.810	7.6335E-02	37.40	50.20	-0.6336	-6.4668E-02
6	7.9650	9.6000	0.1319	40.37	80.93	-0.5613	-5.6462E-02
7	6.5600	7.3400	0.2107	19.33	135.1	-0.2166	-0.1318
8	0.85000	2.5060	2.973	43.31	187.2	2.174	2.568
9	0.60000	1.9700	4.221	0.8357	96.77	3.742	1.558
10	1.3000	1.2700	4.221	0.1855	17.64	2.679	1.180
11	10.000	1.2700	0.8495	1.3368E-03	1.9255E-02	0.000	2.3286E-02
12	10.000	0.0000	1.4992E-07	5.4221E-17	1.0701E-14	7.5767E-16	0.000
			Total	300.3			

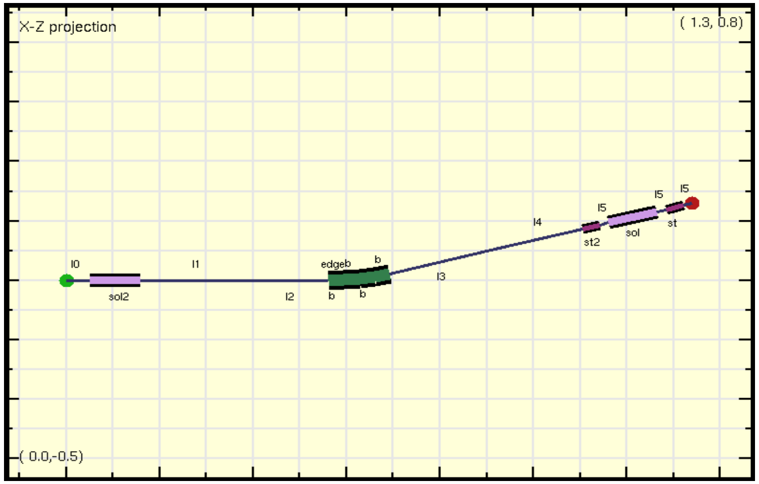




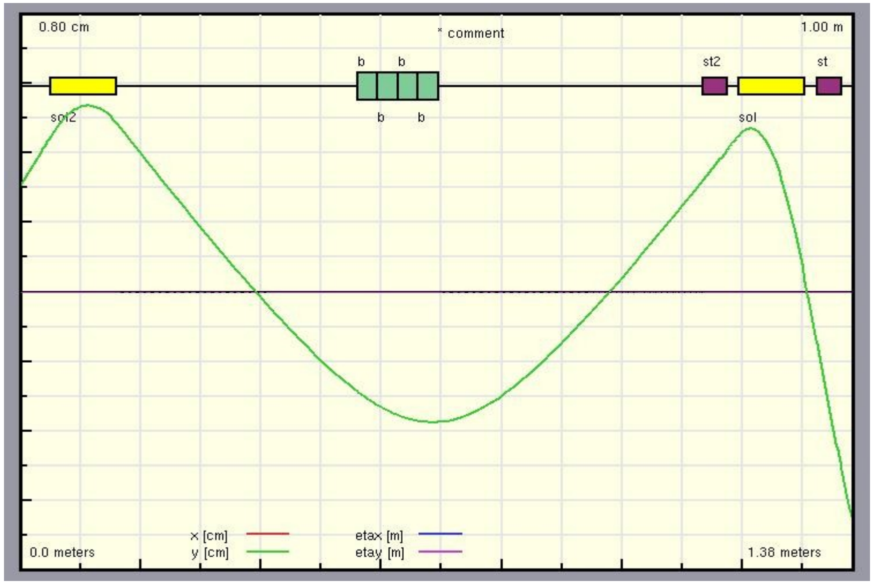
LEBT Configuration

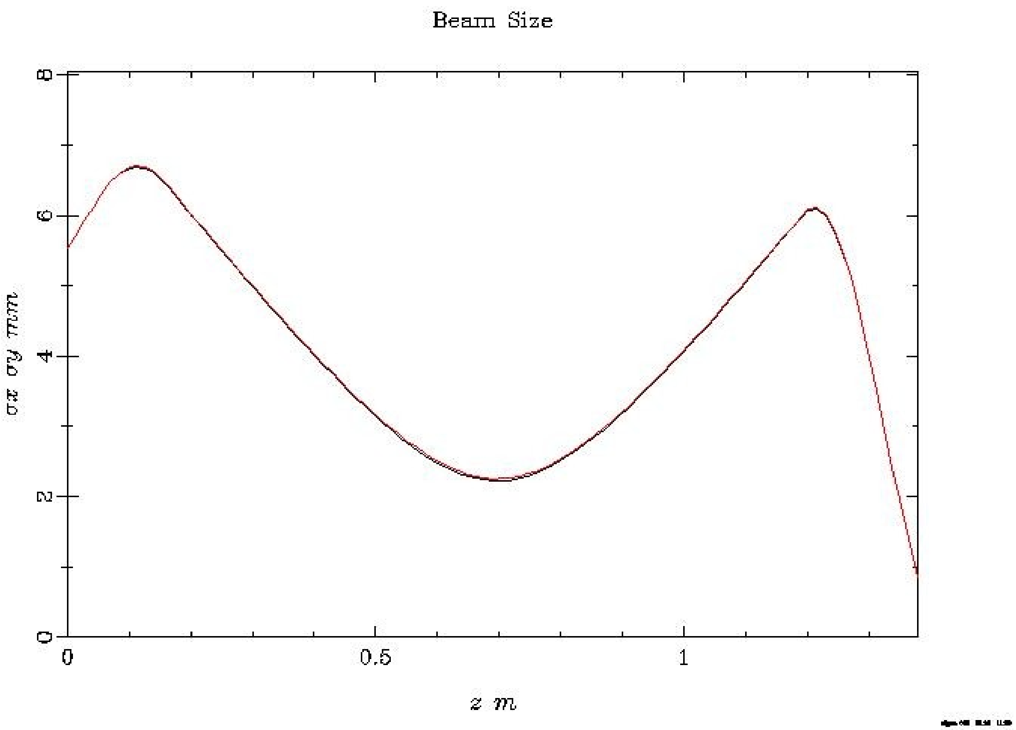
20 keV
5 mA DC beam
>90% neutralization
2 solenoids
2 ion H-minus ion sources
±20 degree selector magnet
chopper at end





Astra macroparticle simulation of LEBT





TLAT

Astra

TLAT is a new code, based on a TRACE3D physics model.   It is an envelope code that correctly incorporates both 2-D and 3-D space charge, deflectors, steering, etc.

Astra is a workhorse of the electron community. It is a macroparticle code with PIC space charge.   It works as well with hadrons and offers extensive graphics and analysis facilities. Accept ion source emittance scan and simulate nonlinear effects.

LEBT Chopper

20 keV beam. $\beta = 0.0065$

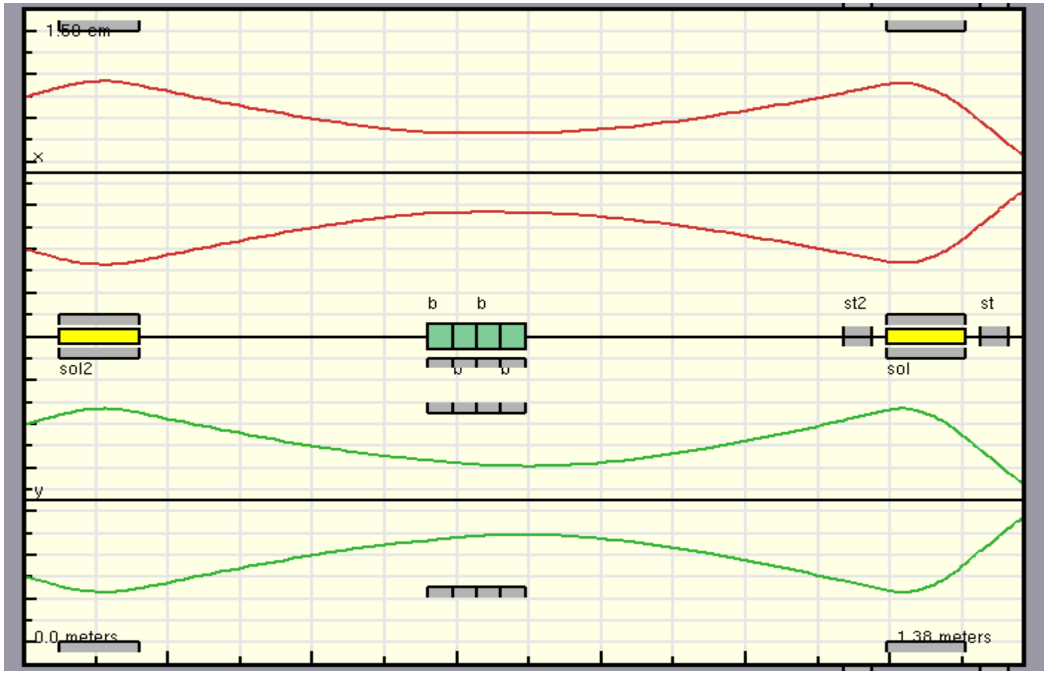
TW chopper for this beam velocity probably not practical

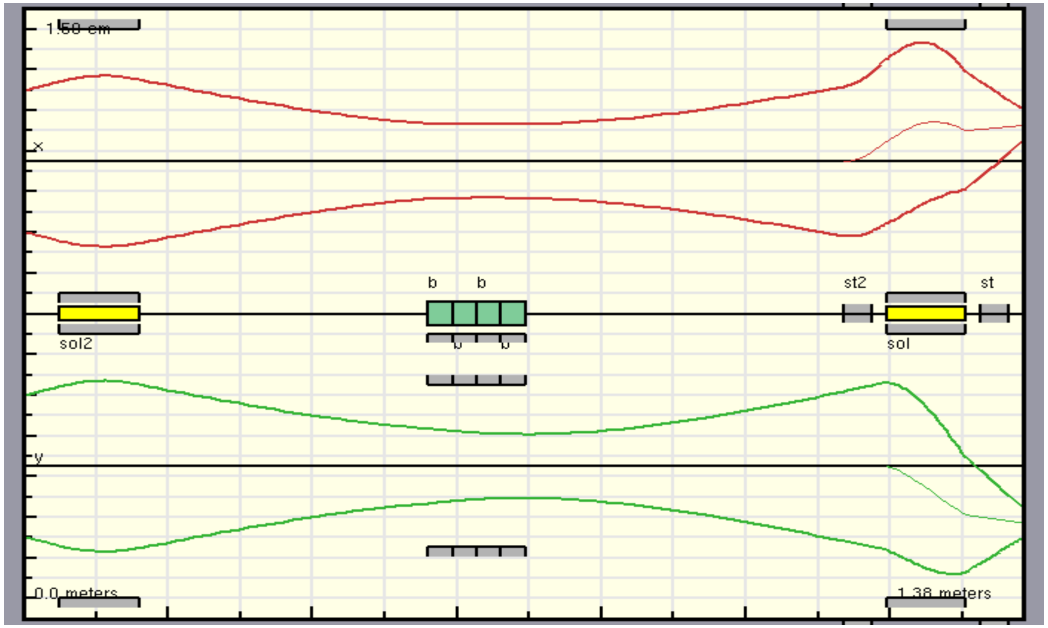
Two locations considered:

- In front of last solenoid
- After last solenoid

For position in front of last solenid, plate spacing > 2 cm.

For effective length of 4 cm, transit time is 20 nsec

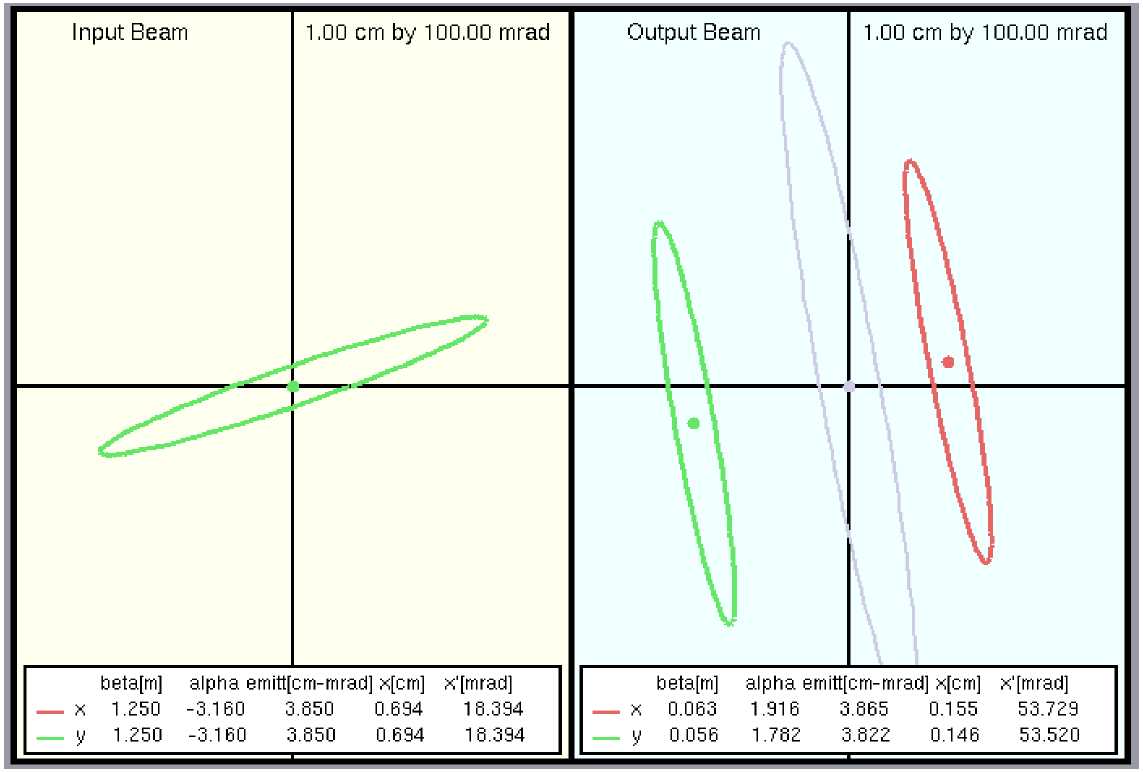




LEBT Chopper displacement of x and y phase spaces at RFQ Entrance

Chopping ahead of last solenoid in x-direction displaces both x and y ellipses.

Gray ellipse is RFQ acceptance ellipse orientation.

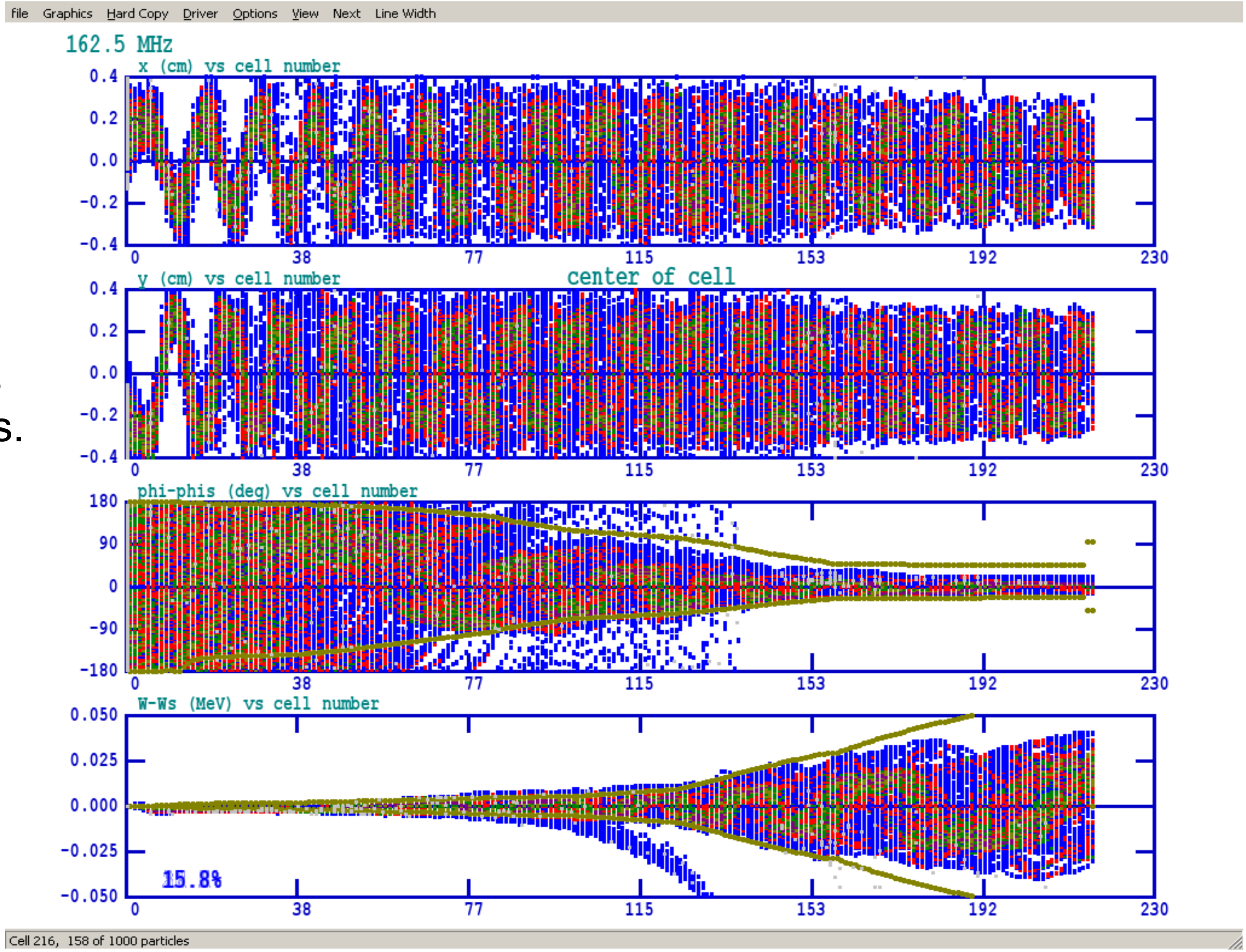


RFQ transmission and output beam characteristics simulated with various chopper deflection field strengths.

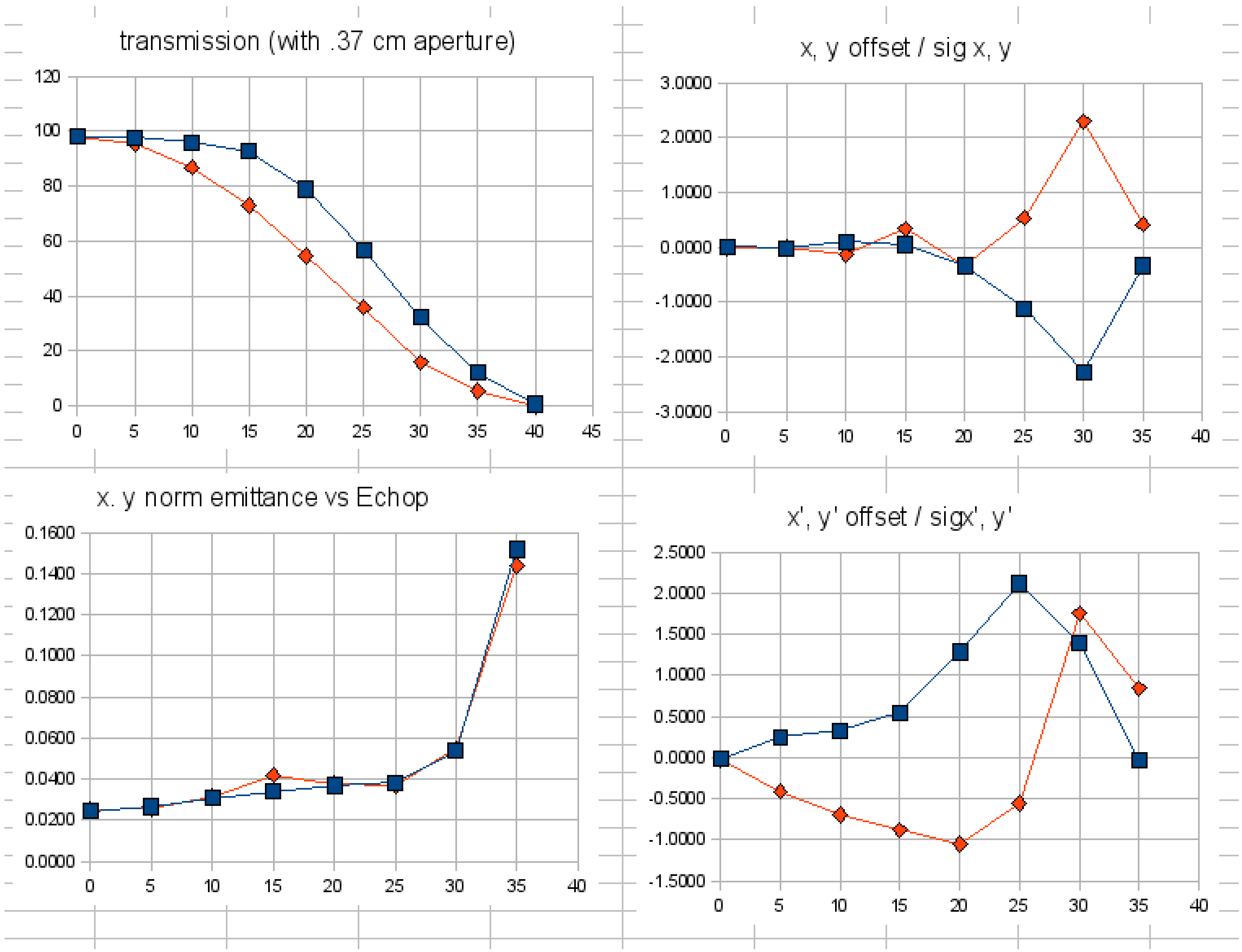
Response of RFQ to displaced entrance beam

Transverse beam undergoes about 17 betatron oscillations.

Output beam offset very dependent on gradient.



RFQ exit beam parameters wrt LEBT chop



Details highly dependent on gradient (tune). Input aperture doesn't help much.

Issues for fast LEBT chopper

20 MHz beam chopper with 10 MHz deflector: 2 zero-crossings per cycle

4 cm long chopper 75 electrical degrees of 10 MHz long

β = 0.0065 too low for a TW chopper design

For square wave, next harmonic of 30 MHz 225 electrical degrees long

Plates > 2 cm apart, shorter chopper will still have long effective length and more nonlinear fields.

Time average of RFQ output beam emittance is large

RFQ phase acceptance $\pm\pi$. Longer chop produces satellite bunches. Shorter chop reduces current within phase acceptance.

Therefore, 20 MHz chopping in LEBT probably not practical.

Issue: LEBT 20 degree Magnet, fast or slow?

Two ways to go: fast laminated magnet or slow solid-core magnet

2-entry port, 20 degree selector magnet.
20 degree entrance angle, 0 degree exit angle
typically 20 cm long, 700 gauss field.
Entrance gap width 6-8 cm wide

Slow magnet: used to switch to a standby ion source in a few seconds

- small, with small gap, 2.5 cm full gap
- Very modest power
- Solid core construction

Fast magnet: used to dynamically switch two ion sources

- 500 microseconds switching time
- much larger gap to reduce inductance to keep switching voltage reasonable
- laminated core
- may require more complex vacuum chamber to reduce eddy currents
- complex power supply: low static voltage, high switching voltage

Selection will depend on beam requirements.

A slow magnet design is very modest, with a power of about 10 watts. It can be made even smaller with a reduced vertical gap.

The magnet is of rectangular geometry, with a ±20 degree entrance angle for the two ion source orbits, and normal exit angle.

A fast magnet will be more challenging. The switching time of 500 microseconds requires laminating the core with high silicon steel, and the power supply must provide a high switching voltage.

As the gap is reduced, the DC current is reduced, but the inductance of the magnet increases, increasing the peak switching voltage. A fast magnet optimizes with a large gap, and a slow magnet with a small gap.

Project-X LEBT Switching Magnet Design

Beam					
	KE	20000	eV	Beam Kinetic Energy	
	pmass	9.38E+08	eV	Beam Mass	
	beta	0.00653		velocity	
	Clight	3.00E+08	m/sec	speed of light	
	Rigidity	0.0204	T-meters	beam rigidity	
	Mu_0	1.26E-06		Mu 0	
Orbit					
	theta	20.0	degrees	bending angle	
	theta	0.349	radians	bending angle	
	L	0.200	meters	magnet length	
	B	0.0356	Tesla	Magnet Field	
	H	28358.1	Amp-turns	Magnet Field	
	rho	0.573	meters	Radius of Curvature	
Magnet					
	full gap	0.040	meters	gap height	
	gw	0.050	meters	gap half-width	
	cw	0.050	meters	coil package width	
	pw	0.040	meters	return leg width	
	ch	0.040	meters	coil package height per pole	
	eta	0.900		magnet efficiency factor	
	s	0.500	meters	steel length of return flux	
	mu_steel	2000		relative to mu_0	
	NI	1268.24		Amp-turns	
	Vgap	8.00E-04	Meters^3	field volume	
	Ugap	0.40	Joules	Stored Energy in gap	
	Vsteel	0.009	Meters^3	Steel Volume	
	Usteel	0.253	Joules	Stored Energy in Steel	
	Full Width	0.280	meters	11.02 inches	
	Full Height	0.200	meters	7.87 inches	
Coil					
	N	50		number of turns, upper and lower coil packages	
	I	25.36	Amperes	Excitation current	
	p	0.70		coil packing factor	
	rho	1.68E-08	Ohm-meter	copper resistivity	
	Lth-winding	30	meters	total winding length	
	Area-wire	5.60E-05	m^2	wire area cross-section, two packages	
	R	0.0090	ohms	coil resistance	
	Pdc	5.79	Watts	DC magnet power	I^2 R
	Volts	0.228	Volts	DC voltage drop	I R
	J	452942	Amps/m^2	wire current density	
	J	0.453	Amps/mm^2	wire current density	
	r_wire	8.444	mm	magnet wire diameter	
Pulse					
	L	2.04E-03	Henries	magnet inductance	2U/I^2
	t_switch	0.0005	seconds	switching rise time	
	dI/dt	101459.1	Amps/sec	switch from + to – field	
	Vpeak	207.18	Volts	switching voltage	L*Idot

LEBT R&D Program

The LEBT will be developed and tested incrementally

Extraction and 20 keV acceleration from the ion source
Electron diversion and trapping
Ion source emittance measurements
Switching magnet then added
Emittance, neutralization time measurements
Matching section into RFQ that accommodates two ion sources operating
at different current levels
Chopper implementation at RFQ entrance
Establish matching parameters required by RFQ

The LEBT will be fully configured and tested during the R&D phase.

The separation of the 20 keV acceleration, the magnetic transport, and the pulsed electric field chopper will ensure high reliability.

RFQ Structure Engineering

Lessons learned from SNS, ADNS, SNS RFQ Replacement engineering studies

RFQ operates CW, but power densities less than half of SNS RFQ at 6% DF.

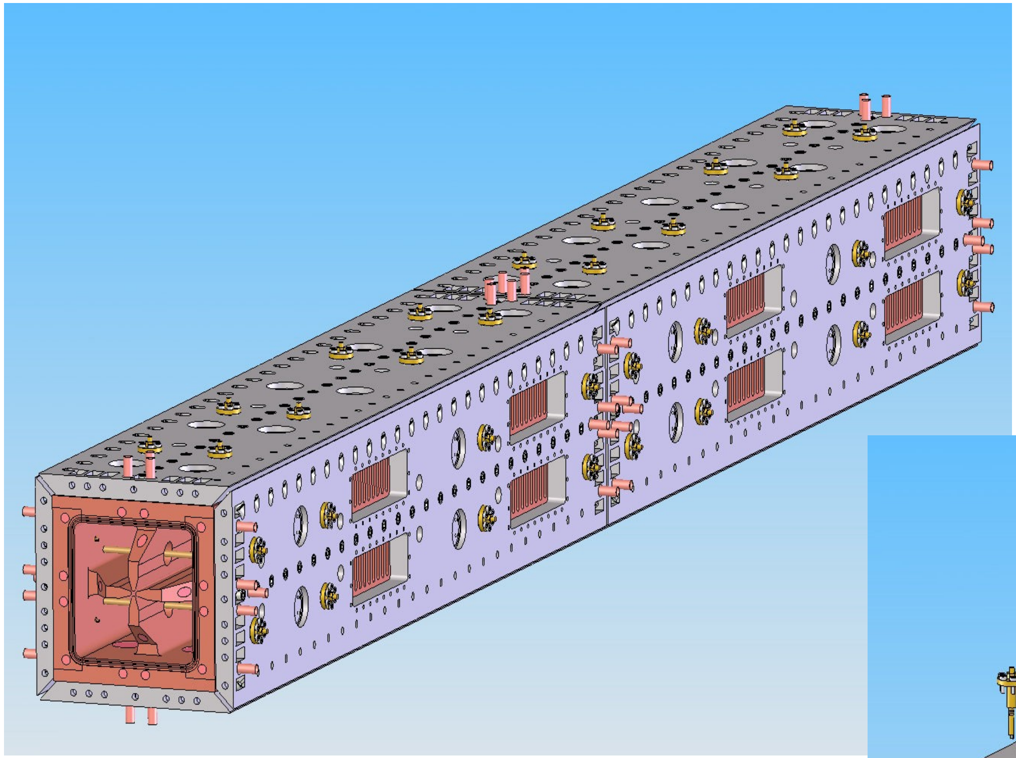
Peak fields about 1.2 kilpatrick

Relatively small length to free-space wavelength may allow no stabilization (TBD).

Will model structure electrodynamics with MWS, do an extensive error analysis
to determine need for stabilization, assembly error tolerances.

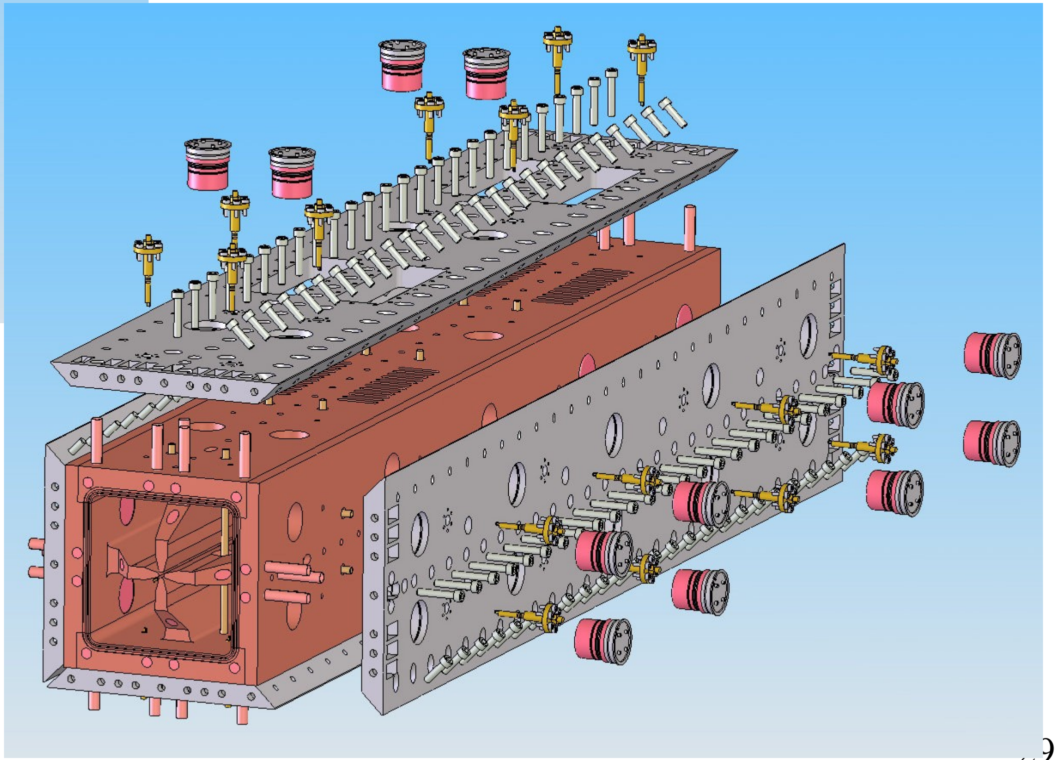
325 MHz RFQ Cross Section Engineering Analysis

162.5 MHz RFQ will use some of these techniques.



Each 133 cm modules has 24fixed tuners, 8 pumping ports.

Brazed copper inner cavity, with a bolted-on stainless steel exoskeleton



266 cm long, two modules

Cooling passages are rifle-bored in the copper substructure.

Two RFQ drive loops provided

Other Physics and Engineering Issues

RFQ output energy and stabilizer configuration

MEBT engineering issues

Limited bandwidth chopper

Beam collimators

MEBT diagnostics

RFQ Output Energy

Reducing the output energy to 2.1 MeV should be considered for the following reasons.

I propose to change the output energy of the RFQ to 2.1 MeV for the following reasons:

This is just below the threshold energy of 2.135 MeV for neutron production in copper with the $Cu^{63}(p,n)Zn^{63}$ reaction. Cu^{63} comprises 69% of natural copper.

The deflection angle of the transverse electric field choppers in the MEBT is increased by the inverse energy ratio, or 19% to 5.95 mrad, increasing the extinction ratio of the choppers. Alternately, the chopper voltage may be reduced. The TW chopper phase velocity must be lowered by 8.3%.

The power deposited in the MEBT collimators is reduced to 84%.

The beam collimators in the MEBT are allowed contain copper, with its good thermal conductivity, without generating neutrons. This would allow the MEBT to be unshielded.

The length of the example 325 MHz RFQ is reduced from 269 to 224 cm, a reduction of 17%, and a reduction of power of up to 17%. The shortened RFQ is 2.4 free-space wavelengths long, raising the possibility of eliminating longitudinal mode stabilizers altogether, further reducing the RF power requirement and simplifying the construction. The RFQ could be made in just two modules.

The RFQ, constructed of copper, would not produce neutrons. The 64 keV X-ray bremsstrahlung, if any, is easily shielded locally. The RFQ need not be located in a shielded area.

The transmission through the RFQ is slightly increased, as the exit end has the smallest aperture.

Note that the 0.015% of deuterium component in hydrogen will not be accelerated and thus will not present a radiation hazard as a potential source of neutrons by breakup or (d,d) reactions.

The downsides:

The spoke cavity following the RFQ must accept a beam velocity $\beta = 0.0669$, an 8.3% reduction from 2.5 MeV. Is the phase slip in the first cavity acceptable?

There may be some additional emittance growth in the MEBT due to the lower energy.

MEBT Physics and Engineering

Biggest issue: thermal control on beam collimators

- Materials choice: strength, sputtering, neutron production ...
- Detailed cooling configuration
- Damage, sputtering, spalling, erosion, etc.
- Beam distribution on collimators with wideband and narrow band choppers

TW Choppers

- Interaction of choppers with beam:
  - erosion from beam halo
- Resistive and reactive losses, thermal control
- Robustness of chopper current-carrying elements in hostile environment
- Bandwidth, phase linearity, efficiency

Neutron production

Diagnostics

Tuning

MEBT R&D Program

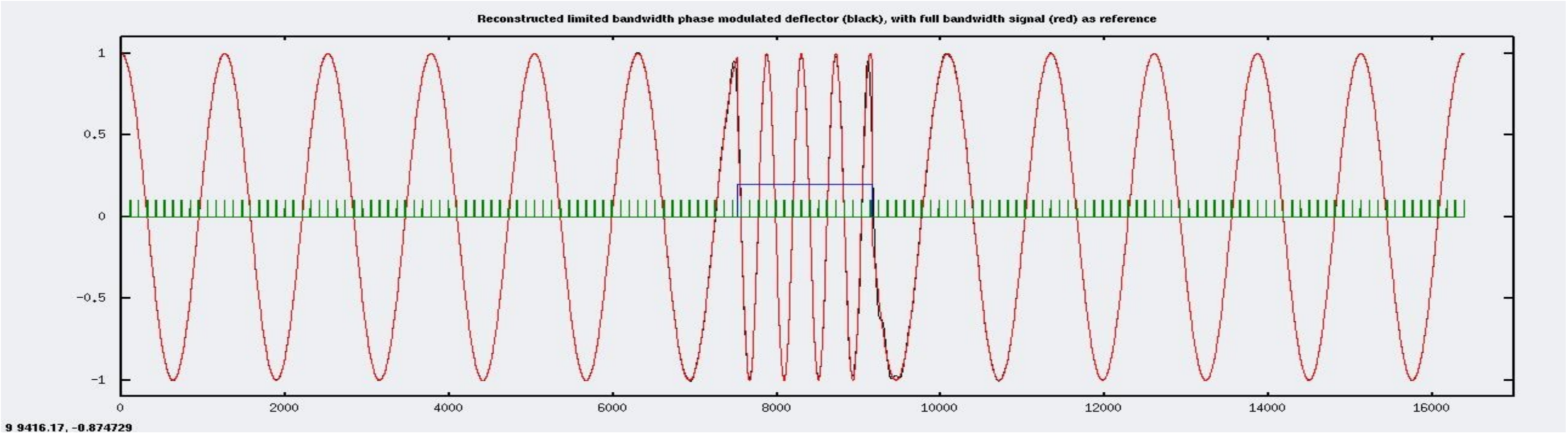
Better define beam requirements
- define what kind of time structure the SCL can handle
- may help with design of a LEBT chopper that mitigates MEBT thermal problems

Choose RFQ frequency and output energy
- Then get on with developing narrow-band chopper scenarios at LBNL

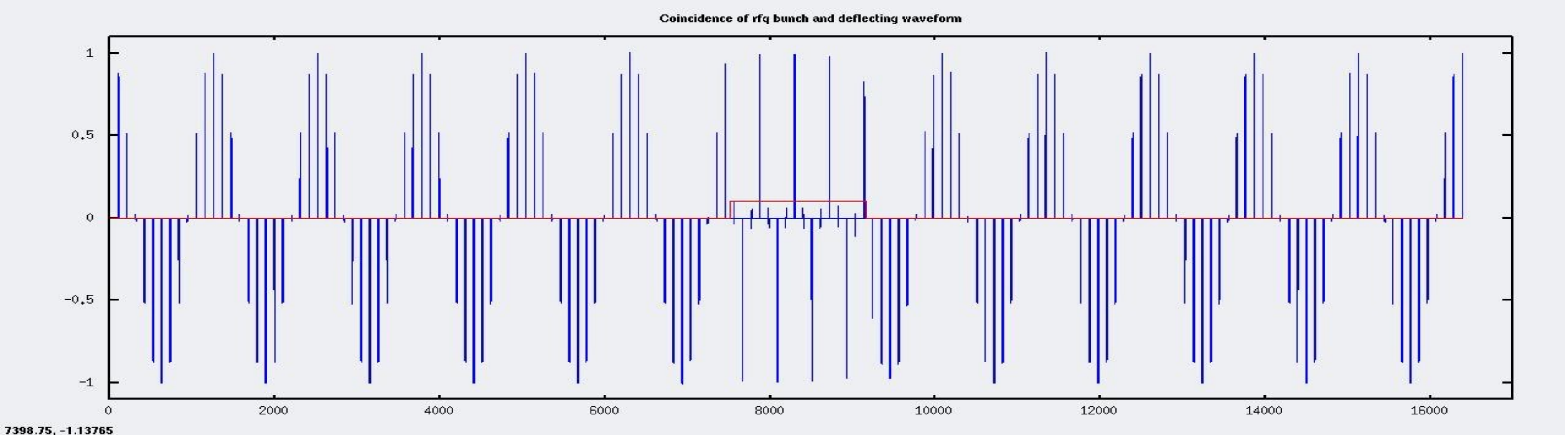
Select leads for critical design issues
- chopper
- chopper power supplies
- beam collimators

Chopper Waveforms (one of many)

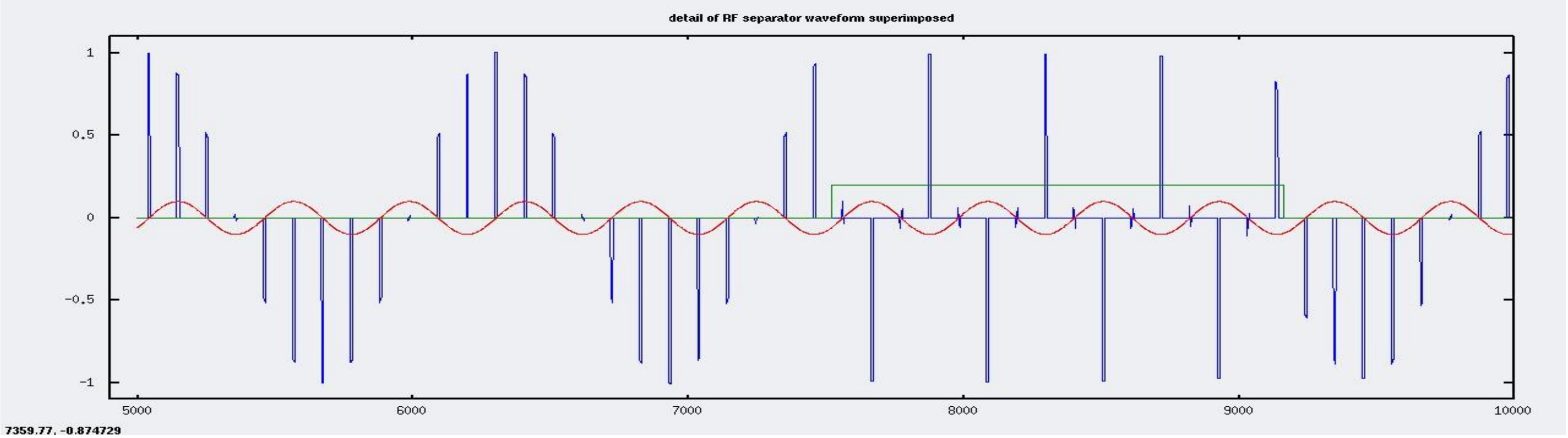
Dual Frequency Chop Example



5/6ths of the pulses removed to collimator



Detail, with RF separator waveform



Chopper Target Power Density Mitigation

Total power is up to 25 kW, steady (10 mA, 2.5 MeV, all chopped out)
More typically 12-20 kW.

Mitigations:

Bi-directional chopping with sinusoidal waveform.
Spreads beam out over a wider swath: factor of 2-3

Split MEBT tune: ribbon shape in MEBT
Further spreads beam out: another factor of 2 or so

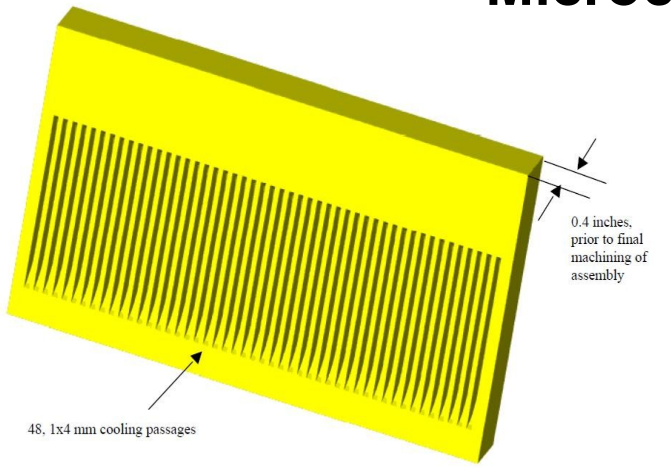
Possible LEBT chop
If the SCL and experiments can handle it: another factor of 2

Lowered RFQ energy
from 2.5 to 2.1 MeV: a factor of 1.2

Total reduction of power density: up to a factor of 10?

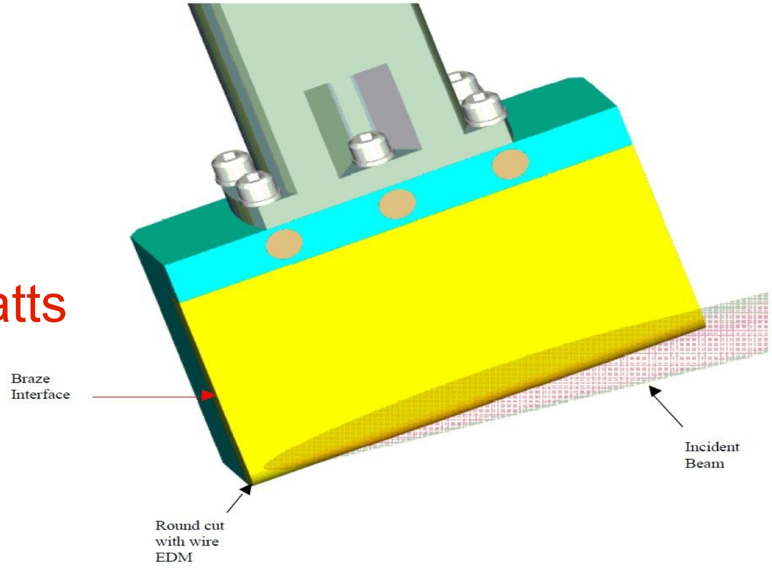
For angle of incidence of, say, 85 degrees, the power density is about 400 W/cm^2 if the beam cross section is 3 cm^2. (4500 W/cm^2 / tan 85 degrees)

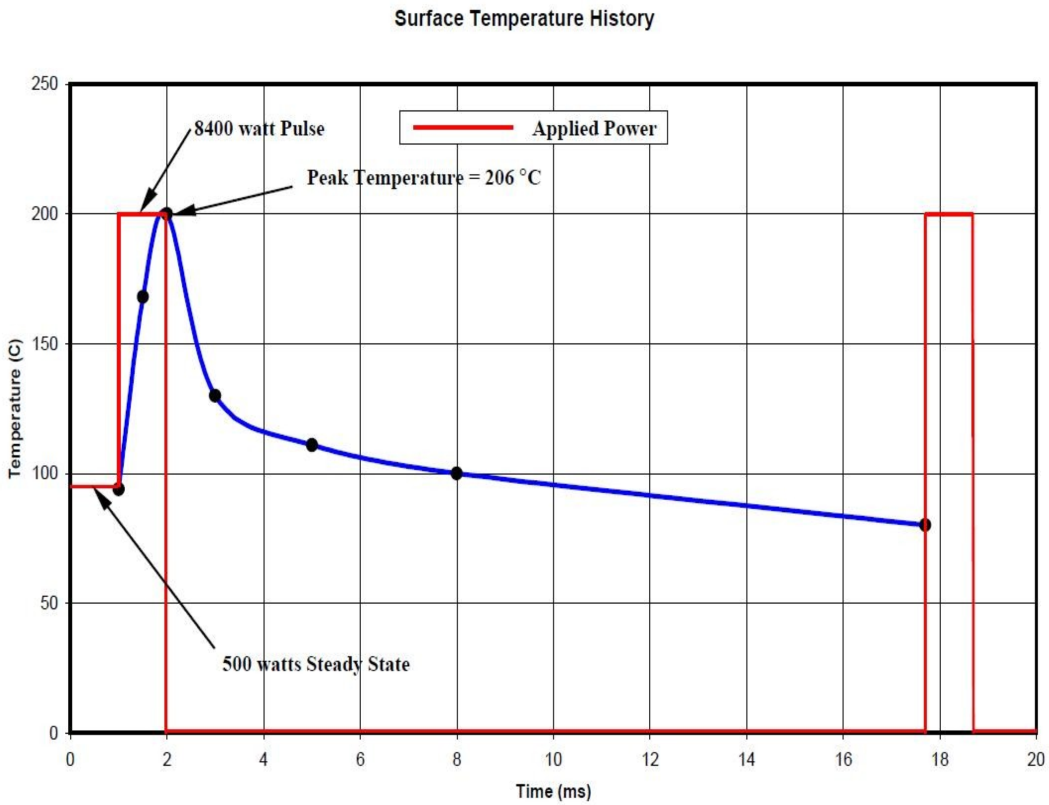
Microchannel Plate Chopper Target for SNS

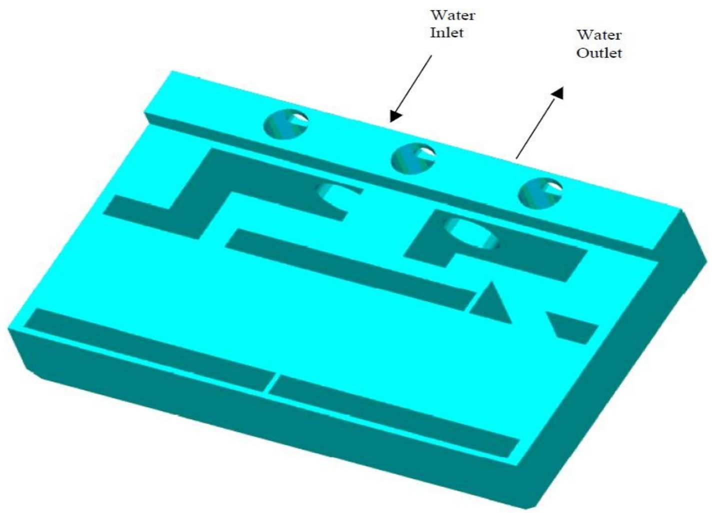


TZM material, developed for high-power X-ray mirrors, adapted for SNS MEBT chopper target.

Average power 500 Watts







Summary

An ion source will be run and characterized at LBNL

A LEBT with 2 solenoids will be constructed and operated with an electrostatic chopper and diagnostics. (The dipole can come later.)

A fast LEBT chopper presents significant emittance issues after RFQ

RFQ frequency now frozen at 162.5 MHz. Good beam dynamics solution obtained

What is RFQ output energy?

Much work needs to be done on the MEBT.

Additional scenarios for the NB chopper must be devised, pending definitions of the physics requirements

The beam collimators for the NB choppers easier task than for WB choppers.